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Accident Rates For Longer Combination Vehicles

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16. Abstract

The objectives of this study were two-fold: (1) to determine the relative accident rates, in accidents per million vehicle miles of travel, of longer combination vehicles (LCV's) and Non-LCV's; and (2) to determine, to the extent possible, the relative accident rates for LCV and Non-LCV subgroups, including Tractors-Semitrailers, STAA Doubles, Rocky Mountain Doubles, Turnpike Doubles, and Triples.

The study methodology consisted of site visits to commercial motor carriers which operate LCV's. Mileage and accident data, covering periods of up to five years, were collected from participating carriers and used to calculate and compare accident rates for LCV and Non-LCV configurations. When practical, comparisons in accident rates among LCV subgroups were also calculated. The differential impacts, if any, which key external factors — area, route, terrain, time-of-day, and driver experience — had on LCV and Non-LCV accident outcomes were also assessed. The severity of LCV versus Non-LCV accidents was examined as well.

This final report documents the results of these investigations.

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METRIC (SI*) CONVERSION FACTORS

APPROXIMATE CONVERSIONS TO SI UNITS

Symbol	When You Know	Multiply By	To Find	Symbol
LENGTH				
in	inches	2.54	millimetres	mm
ft	feet	0.3048	metres	m
yd	yards	0.914	metres	m
mi	miles	1.61	kilometres	km
AREA				
in^2	square inches	645.2	millimetres squared	mm^2
ft^2	square feet	0.0929	metres squared	m^2
yd^2	square yards	0.836	metres squared	m^2
mi^2	square miles	2.59	kilometres squared	km^2
ac	acres	0.395	hectares	ha
MASS (weight)				
oz	ounces	28.35	grams	g
lb	pounds	0.454	kilograms	kg
T	short tons (2000 lb)	0.907	megagrams	Mg
VOLUME				
fl oz	fluid ounces	29.57	millilitres	mL
gal	gallons	3.785	litres	L
ft^3	cubic feet	0.0328	metres cubed	m^3
yd^3	cubic yards	0.0765	metres cubed	m^3

NOTE: Volumes greater than 1000 L shall be shown in m^3.

TEMPERATURE (exact)

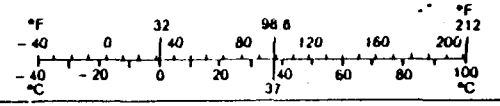
°F	Fahrenheit temperature	5/9 (after subtracting 32)	Celsius temperature	°C

APPROXIMATE CONVERSIONS TO SI UNITS

Symbol	When You Know	Multiply By	To Find	Symbol
LENGTH				
mm	millimetres	0.039	inches	in
m	metres	3.28	feet	ft
m	metres	1.09	yards	yd
km	kilometres	0.621	miles	mi
AREA				
mm^2	millimetres squared	0.0016	square inches	in^2
m^2	metres squared	10.764	square feet	ft^2
km^2	kilometres squared	0.39	square miles	mi^2
ha	hectares (10 000 m^2)	2.53	acres	ac
MASS (weight)				
g	grams	0.0353	ounces	oz
kg	kilograms	2.205	pounds	lb
Mg	megagrams (1 000 kg)	1.103	short tons	T
VOLUME				
mL	millilitres	0.034	fluid ounces	fl oz
L	litres	0.264	gallons	gal
m^3	metres cubed	35.315	cubic feet	ft^3
m^3	metres cubed	1.308	cubic yards	yd^3

TEMPERATURE (exact)

°C	Celsius temperature	9/5 (then add 32)	Fahrenheit temperature	°F



These factors conform to the requirement of FHWA Order 5190.1A.

* SI is the symbol for the International System of Measurements

HIGHLIGHTS OF THE STUDY

OVERVIEW

- Seventy-five commercial motor carriers participated in this study to compare the accident rates of longer combination vehicles (LCV's) to Non-LCV's. All participants operated both LCV's and Non-LCV's.

- Though domiciled in 17 States, participants operated commercial motor vehicles throughout the United States.

- Forty percent of study participants maintained fleets with 20 power units or fewer; 33 percent: 21-75 power units; 21 percent: 76-999 power units; and 5 percent: over 1,000 power units.

- Accident and exposure data used in the study covered the period 1989-94.

- Participants accumulated a total of 2.8 billion usable vehicle miles of travel (VMT) during the study period. This VMT correlated with 4,518 accidents involving LCV's and Non-LCV's.

- Non-LCV travel accounted for 79 percent of the study's VMT, but 88 percent of the accidents. LCV travel accounted for 22 percent of the VMT, but only 12 percent of the accidents.

- LCV's were defined to include (1) Rocky Mountain Doubles, (2) Turnpike Doubles, (3) STAA Doubles/GVW Over 80,000 Pounds, and (4) Triples. Non-LCV's included (1) Tractors-Semitrailers, and (2) STAA Doubles/GVW 80,000 Pounds Or Less.

ACCIDENT RATES

- For the 75 carriers examined in this study, LCV's were much less likely than Non-LCV's to be involved in accidents. These findings pertain only to the carrier population from which the study sample was drawn.

- Among study participants, the mean accident rate was 0.88 accidents per million VMT for LCV's versus 1.79 accidents for Non-LCV's; in other words, Non-LCV's were more than twice as likely as LCV's to be involved in accidents. The difference in the mean accident rates was found to be statistically significant.

- Differences in aggregate accident rates among specific LCV configurations were identified in this study, although none of these differences were determined to be statistically significant. The mean accident rates per million VMT for Turnpike Doubles, Rocky Mountain Doubles, and Triples were 1.02, 0.79, and 0.83, respectively.

- Carrier fleet size did not appear to account for differences in accident rates between LCV's and Non-LCV's. However, the LCV accident rate was considerably lower for all fleet sizes than the Non-LCV rate.

- LCV's and Non-LCV's had nearly equal probabilities of involvement in fatal crashes. When fatal and injury crashes were examined in tandem, however, the LCV accident rate was 50 percent lower than the Non-LCV rate.

- Non-LCV's were 2.1 times more likely than LCV's to be involved in collisions, and 1.8 times more likely to be involved in non-collisions; these differences were statistically significant. Rocky Mountain Doubles were less likely than Turnpike Doubles and STAA Doubles/GVW Over 80,000 Pounds to be involved in collisions.

- LCV's were almost twice as likely as Non-LCV's to overturn, and LCV Doubles were more likely than Tractors-Semitrailers to jackknife.

ACCIDENT SEVERITY

- When accidents occurred, the consequences tended to be more severe when LCV's were involved than when they were not involved.

- LCV crashes resulted in an average of 2.9 deaths per 100 accidents, versus 1.5 deaths for Non-LCV crashes. Turnpike Doubles experienced 5.2 deaths per 100 accidents.

- LCV crashes resulted in 15.9 injuries per 100 accidents, versus 16.7 injuries for Non-LCV crashes.

- LCV crashes resulted in 37.3 tow-aways per 100 accidents, versus 18.8 tow-aways for Non-LCV crashes.

EXTERNAL FACTORS

- Differences in LCV and Non-LCV accident rates were not adequately explained by the external factors examined in this study.

- LCV's appeared more vulnerable to involvement in accidents in urban — rather than rural — settings.

- Most accidents examined in this study occurred on arterial — not interstate — roads. Nevertheless, LCV's seemed to experience proportionally more accidents than Non-LCV's on interstate roads, but proportionally fewer accidents on arterial roads.

- Experienced drivers generally had fewer accidents, regardless of whether they operated LCV's or Non-LCV's. Differences in LCV and Non-LCV accident rates were observed among the driver groups, although these differences were not always statistically significant. Anecdotal data suggests that LCV carriers tended to assign their "safest" drivers to LCV's.

1.0 INTRODUCTION

Public policy debate, in recent years, has focused increasingly on the issue of commercial vehicle safety, particularly as the sheer presence and size of trucks on our nation's highways has grown. The current dialogue over truck size involves complex safety, infrastructure, environmental, and economic issues, and the outcome will likely have far-reaching implications for the trucking industry, shippers, consumers and travelers, and the nation's roads. Decisions will need to be made about whether further restrictions should be imposed — or current restrictions lifted — on the operation of large commercial vehicles.

This report focuses on a particular, specialized type of large truck — *longer combination vehicles* (LCV's). LCV's may weigh up to 164,000 pounds and be as long as 123 feet. Currently, the operation of LCV's is restricted by Federal law to selected highways and roads in 23 States.

This report summarizes the results of a 34-month study intended, essentially, to respond to a single question: *Are the accident rates of longer combination vehicles different from those of other combination vehicles?* The study was performed on behalf of the Federal Highway Administration (FHWA), U.S. Department of Transportation, by The Scientex Corporation, under FHWA Contract Number DTFH61-94-C-00178. The research was conducted from January 1994 - October 1996.

1.1 BACKGROUND

A longer combination vehicle refers to any truck combination with (1) two or three trailers, and (2) a trailer length in excess of twin 28.5-foot trailers or a gross vehicle weight (GVW) in excess of 80,000 pounds. As shown in Figure 1, LCV's include STAA Doubles/GVW Over 80,000 Pounds, Rocky Mountain Doubles, Turnpike Doubles, and Triples. Non-LCV's include Tractors-Semitrailers and STAA Doubles/GVW 80,000 Pounds or Less.

The term "STAA Double" refers to a special vehicle type authorized by the *Surface Transportation Assistance Act* (STAA) of 1982. The STAA permitted a twin-trailer vehicle to operate in all States, provided (1) the trailer did not exceed 28.5 feet in length, and (2) the GVW of the vehicle did not exceed 80,000 pounds. STAA Doubles, when their GVW's exceed 80,000 Pounds, are classified as LCV's.

LCV's are presently allowed to operate in the 23 States identified in Figure 2. Most States restrict the operation of LCV's to specific roads and routes (e.g., turnpikes).

1.2 CURRENT AND RELATED LEGISLATION

The *Intermodal Surface Transportation Efficiency Act* (ISTEA) of 1991, Public Law 102-240, is the controlling Federal Law for the operation of LCV's. ISTEA, which reauthorized Federal-Aid

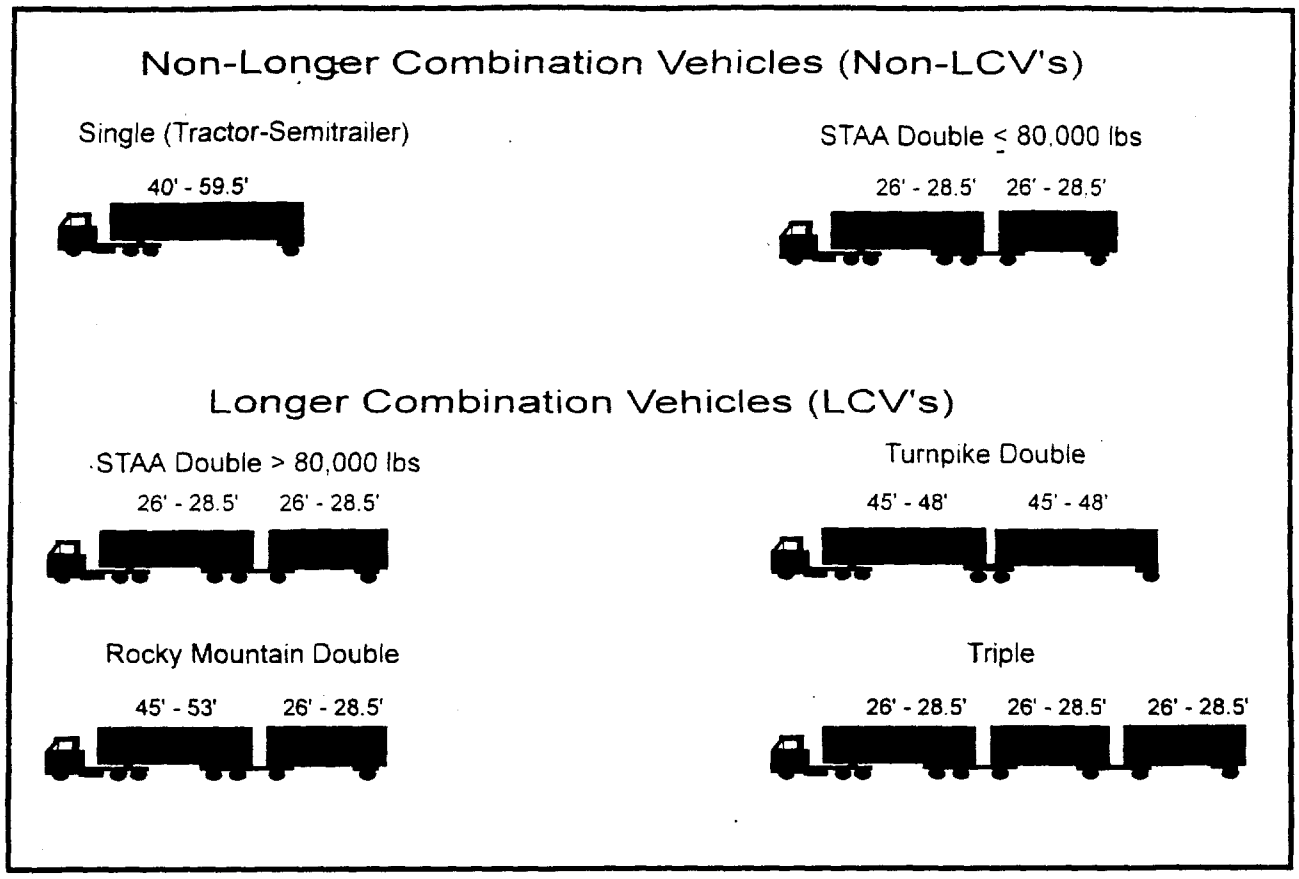


Figure 1. Non-LCV and LCV tractor-trailer combinations examined in this study.

Highway and Transit Programs through Fiscal Year 1997, limited the operation of LCV's to the States, routes, and operating conditions in effect on or before June 1, 1991. The legislation provided States with the authority to further restrict LCV operations.

1.3 SUMMARY OF PAST STUDIES

Numerous previous studies have attempted to address the issue of LCV safety. For example, Larson and Hanscom (1984)[1] performed a literature review which focused on the impact of truck length and articulation on traffic operations. The review compared Tractors-Semitrailers, Doubles, and Triples with respect to speed, passing, merging, weaving, gap acceptance, weather-related operations, curving, ramping, braking, human factors, highway capacity, and crash barrier adequacy. The major conclusions drawn were:

[1] Larson, E.E. and Hanscom, F.R., *Traffic Operational Impact of Large Trucks: A Literature Review*, Federal Highway Administration, October 5, 1984.

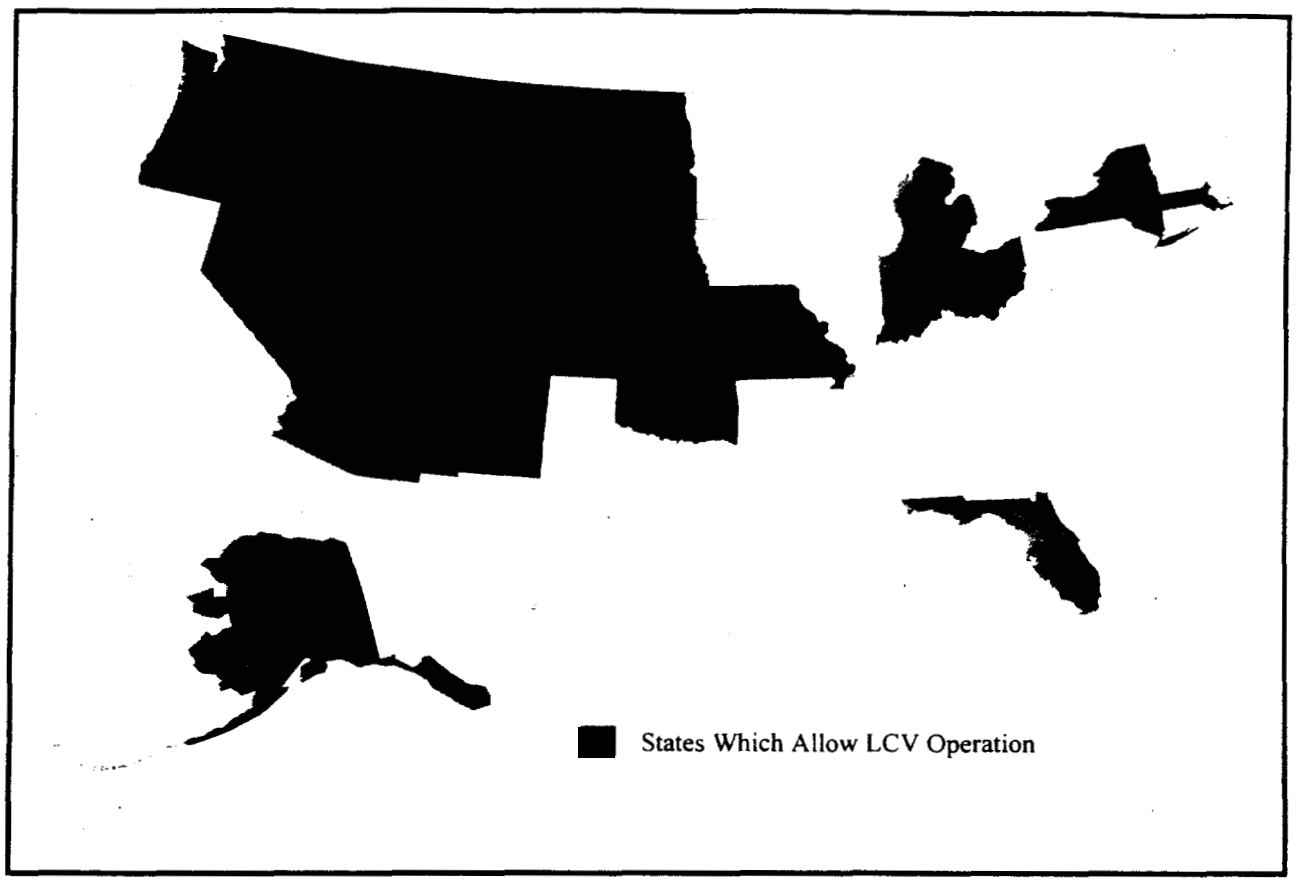


Figure 2. States allowing LCV operation on selected roadways.

- All large trucks create potentially dangerous speed effects on upgrades; the effects are more pronounced for Triples and Doubles than for Singles.
- Rear trailer sway creates operational difficulties for other traffic during weaving, merging, and passing, particularly on two-lane highways.
- The impacts of driver experience on larger truck operations are not known. The effects that larger trucks have on drivers of the other vehicles they encounter are also not known.

Vallette and Hanscom (1981)[2], comparing Doubles to Singles, found that:

- Doubles had a higher mean accident rate than Singles, particularly when both vehicles were operating empty.

[2] Vallette, G.R. and Hanscom, F.R., *The Effect of Truck Size and Weight on Accident Experience and Traffic Operations*. Final Report No. FHWA/RD-80/136. Federal Highway Administration. Washington, D.C., July 1981.

- A disproportionate number of accidents involving Doubles occurred on moderate-to-steep downgrades, rather than on upgrades; accidents involving Singles were equally distributed between downgrades and upgrades.

- Doubles had a higher accident rate than Singles on rural freeways.

- In multi-vehicle truck accidents, Doubles were rear-ended more often than Singles.

- Doubles and Singles had similar injury accident rates.

- Accident rates were consistent across driver age for both Doubles and Singles, except that rates were higher for drivers aged 29 years and under.

- There was an inverse relationship between level of driver experience and accident rates, i.e., accident rates decreased as professional driving experience increased.

A 1985 FHWA[3] study, mandated by the STAA of 1982, concluded that:

- LCV's were more productive and had better fuel consumption than Singles. LCV's, however, were less able to back up, had more overweight potential, and were less able to maintain speed and accelerate.

- Rocky Mountain Doubles and Triples had less stability and more trailer sway than either Singles or Turnpike Doubles.

- Existing LCV's had very low accident rates because of special conditions governing their operations; performance and handling limitations of LCV's might create safety problems if these vehicles were operated under a broader variety of road, environmental, and traffic conditions.

- Expanded use of LCV's could, conceivably, reduce the industry's total accident rates per ton-mile since LCV's carry more freight for the same amount of travel.

In 1992, Sullivan and Massie[4] concluded that proportionally more fatal accidents involving Doubles occurred on limited access roads than on major arteries; also, Doubles, as compared to Singles, had a higher incidence of nighttime accidents and a lower incidence of daytime accidents. Zegeer, Hummer, and Hanscom (1986)[5] found that the length and configuration of trucks created more of

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[3] *The Feasibility of a Nationwide Network for Longer Combination Vehicles*, Federal Highway Administration, Washington, D.C., June 1985.

[4] Sullivan, K.P. and Massie, D.L., *Trucks Involved in Fatal Accidents, FACTBOOK 1989*, UMTRI Report 92-19, Center for National Truck Statistics, The University of Michigan Transportation Research Institute, Ann Arbor, Michigan, October 1992.

[5] Zegeer, C.V., Hummer, J.E., and Hanscom, F., *The Operation of Larger Trucks on Roads with Restrictive Geometry*, Final Report No. FHWA/RD-86/157, Federal Highway Administration, Washington, D.C., July 1986.

a hazard than did truck width. Gericke and Walton (1981)[6] concluded that larger trucks impacted the following highway geometrics: (1) General Design Elements (e.g., stopping and passing, sight distance, pavement widening on curves, and critical lengths of grades); and (2) Intersection Design Elements (e.g., minimum design for turning radii, widths for turning lanes, sight distance for at-grade intersections, and median openings).

In its 1993 *Larger-Dimensioned Vehicle Study*[7], FHWA compared the accident rates and general safety fitness of single- and multi-trailer combinations. The study concluded, in part, that "...multi-trailer trucks have a lower fatal involvement rate than single-trailer trucks for their current distribution of travel by functional class, but [that] a similar rate would result if they had the same distribution of travel."

The problem with this study was the low volume of data provided by States. For example, 13 States originally agreed to collect data from 1983 to 1991. However, only four States ultimately furnished data for the majority of these years, which obviously limited the extent to which the study results could be generalized.

Due to Congressional concerns over the safety factors involved in the operation of LCV's, the Subcommittee on Surface Transportation within the House of Representatives, in October 1990, requested that the General Accounting Office (GAO)[8] study the issue. GAO reviewed the extent of LCV use, summarized the results of numerous studies on LCV safety, and identified major operational characteristics which affect LCV safety.

The GAO observed that:

- Studies of LCV's have resulted in disparate conclusions, including findings that multiple-trailer vehicles are both more and less likely to be involved in accidents than other commercial vehicles.

- The reasons for the opposing conclusions rest with the different approaches used by the researchers, and the difficulty of collecting and interpreting the data used in the studies.

Hence, the central conclusion of the GAO report was that "the safety of LCV's is still largely unknown."

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[6] Gericke, O.F. and Walton, C.S., *Effect of Truck Size and Weight on Rural Roadway Geometric Design (and Redesign) Principles and Practices*, Transportation Research Board Record No. 806, 1981.

[7] *Larger-Dimensioned Vehicle Study*, Final Report, Federal Highway Administration, Washington, D.C. September 1993.

[8] *Truck Safety: The Safety of Longer Combination Vehicles Is Unknown*, United States General Accounting Office, Washington, D.C., March 1992.

2.0 SCOPE OF THE STUDY

The objectives of this research effort were two-fold:

- To determine the relative accident rates — in accidents per million vehicle miles of travel — for LCV's and Non-LCV's.

- To determine, to the extent allowable by the data, the relative accident rates for LCV and Non-LCV subgroups (i.e., Tractors-Semitrailers, STAA Doubles, Rocky Mountain Doubles, Turnpike Doubles, and Triples).

When possible, the impact of key external factors on LCV and Non-LCV accident rates was also to be examined. Pertinent factors included (1) carrier fleet size, (2) highway type and environmental conditions, and (3) driver experience.

The planned approach to this study revolved around site visits to commercial motor carriers operating both LCV's and Non-LCV's. Eligible carriers were to be asked to furnish, voluntarily, historical data on (1) LCV and Non-LCV accidents, and (2) vehicle miles of travel by LCV and Non-LCV configurations. Accident and mileage data, taken together and aggregated across carriers, was then to be used to calculate and compare the relative rates of accidents.

FHWA defined this general approach to the study. The Scientex Corporation was selected to refine and execute the study methodology.

3.0 STUDY METHODOLOGY

This section of the report describes the principal features of the study methodology, including approaches used to (1) sample the LCV carrier population, (2) collect and process the required data, and (3) analyze the results. The entire study was conducted during a 34-month period, from January 1994 - October 1996; the data-collection portion of the study was completed over 17 months, from August 1994 - December 1995. The data-collection instruments and procedures used in the study were reviewed and approved by the Office of Management and Budget (OMB No. 2125-0556) prior to the commencement of carrier site visits.

3.1 SUMMARY

The study methodology consisted, primarily, of site visits to commercial motor carriers which operate LCV's. *Mileage* and *accident* data, covering periods of up to five years, were collected from participating carriers and used to calculate and compare accident rates for LCV and Non-LCV configurations. When practical, comparisons in accident rates among LCV subsets — e.g., Rocky Mountain Doubles versus Turnpike Doubles and LCV Doubles versus Triples — were also calculated. The differential impacts, if any, which *area* (urban/rural), *route* (interstate/arterial), *terrain* (level/mountainous), *time-of-day*, and *driver experience* had on LCV and Non-LCV accident outcomes were also assessed. The *severity* of LCV versus Non-LCV accidents was examined as well.

3.2 TERMINOLOGY

Specialized terminology used in this report is defined in the Glossary. Several key terms, central to the study methodology, are also identified and discussed below.

3.2.1 Vehicle Configurations

As shown previously, in Figure 1, vehicle combinations operated by study participants were classified either as *LCV's* or *Non-LCV's*.

LCV's. In this report, LCV's are catalogued as:

- ***STAA Doubles/GVW Over 80,000 Pounds***,
- ***Rocky Mountain Doubles***,
- *Turnpike Doubles*,
- *Triples*, or
- *Other*.

Other refers to the relatively small number of "hybrid" vehicles which met the legal definition of LCV's but did not fit neatly into the established LCV categories. Examples of *Other* include Rocky Mountain Doubles with small trailers or wagons attached to the rear, and vehicles modified or adapted to transport specialized cargo.

Non-LCV's. In this report, Non-LCV configurations are catalogued either as:

- *Tractors-Semitrailers* (often referred to as *Singles*), or
- *STAA Doubles/GVW 80,000 Pounds or Less.*

Mileage and accident data for a third Non-LCV configuration, *Straight Trucks*, were also collected and used as validation keys (i.e., to account for total miles travelled and accidents experienced by participating carriers). Straight Truck statistics, however, are not presented in this report.

3.2.2 Mileage

Vehicle miles of travel (VMT) is defined as the total miles accumulated by all power units operated (owned and leased) by a given carrier during a specified time period. VMT may be calculated for all vehicles in a fleet, or only for those vehicles meeting prescribed characteristics.

Carriers participating in this study contributed up to five years of VMT data. The five-year period covered the years 1989-93 for carriers visited in 1994, and 1990-94 for carriers visited in 1995. Many carriers could not furnish usable VMT data for all five years, but were able to supply the information for selected years only. Generally, carriers were better able to provide usable VMT data for the more recent years than for the earlier years — nearly all carriers were able to furnish VMT for 1993, whereas relatively few could provide VMT for 1989.

For a carrier's VMT data for a given year to be "counted" in the study, all of the following criteria had to be met:

- The carrier had to have engaged in some LCV travel for the year.
- The carrier had to have reliable VMT data for the entire year, not just some portion of the year.
- The carrier had to be able to differentiate, at a minimum, between LCV and Non-LCV VMT.
- The carrier had to have reliable accident data for the entire year and be able to differentiate, at a minimum, between LCV and Non-LCV accidents.

During data-processing, mileage and accident data were aggregated for all applicable years; consequently, the analysis in this report does not differentiate between calendar years.

3.2.3 Accidents

Data were collected on all accidents involving participating carriers in each year for which usable VMT data were also available. For a carrier's accidents for a given year to be "counted" in the study, all of the following criteria had to be met:

- All accidents which occurred during the year needed to be identified in the carrier's Accident Register or comparable data repository.
- The carrier had to have corresponding VMT data for the entire year and be able to differentiate, at a minimum, between LCV and Non-LCV miles.
- All accident reports had to contain sufficient detail to differentiate, at least, between LCV's and Non-LCV's.

Pertinent definitions of "accident" used in this report are summarized below.

Accident. In this report, *accident* is defined as an occurrence involving a commercial motor vehicle operating on a public road in interstate or intrastate commerce which requires (1) the filing of a police accident report, (2) the filing of an insurance accident report, or (3) the recording of information about the occurrence in the motor carrier's Accident Register.[9] Except where noted, the data in this report cover all accidents.

Collision Accident. As used in this report, a *collision* is an accident between a commercial motor vehicle and another object. Collision objects include other motor vehicles, trains, bicycles, pedestrians, animals, and fixed objects along the road.

Non-Collision Accident. A *non-collision* is a commercial vehicle accident in which the primary event does not involve hitting another object. Non-collision accidents include jackknifes, overturns, fires, cargo shifts and spills, and running off the road.

Threshold Accident. In this report, a *threshold accident* refers to an occurrence involving a commercial motor vehicle operating on a public road in interstate or intrastate commerce which results in (1) a fatality, (2) bodily injury requiring medical treatment away from the scene of the accident, or (3) one or more commercial vehicles incurring disabling damage requiring the vehicle to be towed from the scene of the accident. Threshold accidents are specialized subsets of total accidents.

Accident Rate. The *accident rate* specifies the rate at which accidents meeting prescribed characteristics occur. In this report, accident rates are normalized per one million VMT — an accident rate of "2.50" means that for every million miles travelled, an average of 2½ accidents occurred.

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[9] Excluded from this definition are (1) occurrences on private property, (2) occurrences entailing only the boarding and alighting from a stationary motor vehicle, and (3) occurrences entailing only the loading and unloading of cargo.

Accident Severity Rate. This represents the likelihood that accidents, when they occur, will involve fatalities or injuries. In this report, *severity rates* are normalized per 100 accidents — an injury rate of "15.0" means that for every 100 accidents, an average of 15 injuries requiring medical treatment away from the accident scene occurred.

3.2.4 External Factors

To be able to accommodate variations in data maintained by the carriers participating in the study, definitions of the following terms were necessarily imprecise. When sufficient information was available, these terms were applied both to the VMT and accidents experienced by a given carrier.

Area. *Area* is defined as (1) urban or (2) rural. *Urban* refers to miles travelled in and around metropolitan areas. All other travel is termed *rural*.

Route. *Route* is defined as (1) interstate or (2) arterial. *Interstate* refers to miles travelled on the U.S. Interstate Highway System. All other travel is termed *arterial*.

Terrain. *Terrain* is defined as (1) level or (2) rolling/mountainous. *Level* refers to miles travelled where there are little or no discernible changes in road elevations. Miles travelled where there are discernible changes in elevation are termed *rolling/mountainous*.

Time-of-Day. *Time-of-day* is defined as (1) daytime or (2) nighttime. Carriers identified the total miles they travelled during daylight versus those travelled at night. Individual accidents were classified as occurring during the daytime or nighttime using sunrise/sunset values by region and month in the *Farmers' Almanac*.

Driver Experience. Total *professional driving experience* refers to the aggregate number of years a driver has operated commercial motor vehicles. It is defined as: less than one year (<1); at least one year, but less than three years (1-3); at least three years, but less than five years (3-5); at least five years, but less than seven years (5-7); and seven or more years. (≥7).

3.3 STUDY POPULATION

In support of this study, States allowing LCV operations were invited by FHWA to furnish lists of carriers in their respective States holding active LCV permits. Nineteen States, identified in Figure 3, responded to the FHWA request within the designated timeframes.

While several respondents were able to identify those carriers in their States specifically holding LCV permits, this was not typically the case. Many State lists did not differentiate between LCV permit holders and holders of other oversized vehicle permits; other lists identified carriers authorized to operate multi-trailer configurations, but did not indicate which of these carriers were actually operating LCV's. Another problem was the currency of information — permit data, even when they pertained specifically to LCV's, were oftentimes out of date; carriers who previously operated LCV's may no longer have been doing so. For all these reasons, it could not be assumed

that carriers, even though they appeared on one or more of the State-furnished lists, necessarily operated LCV's.

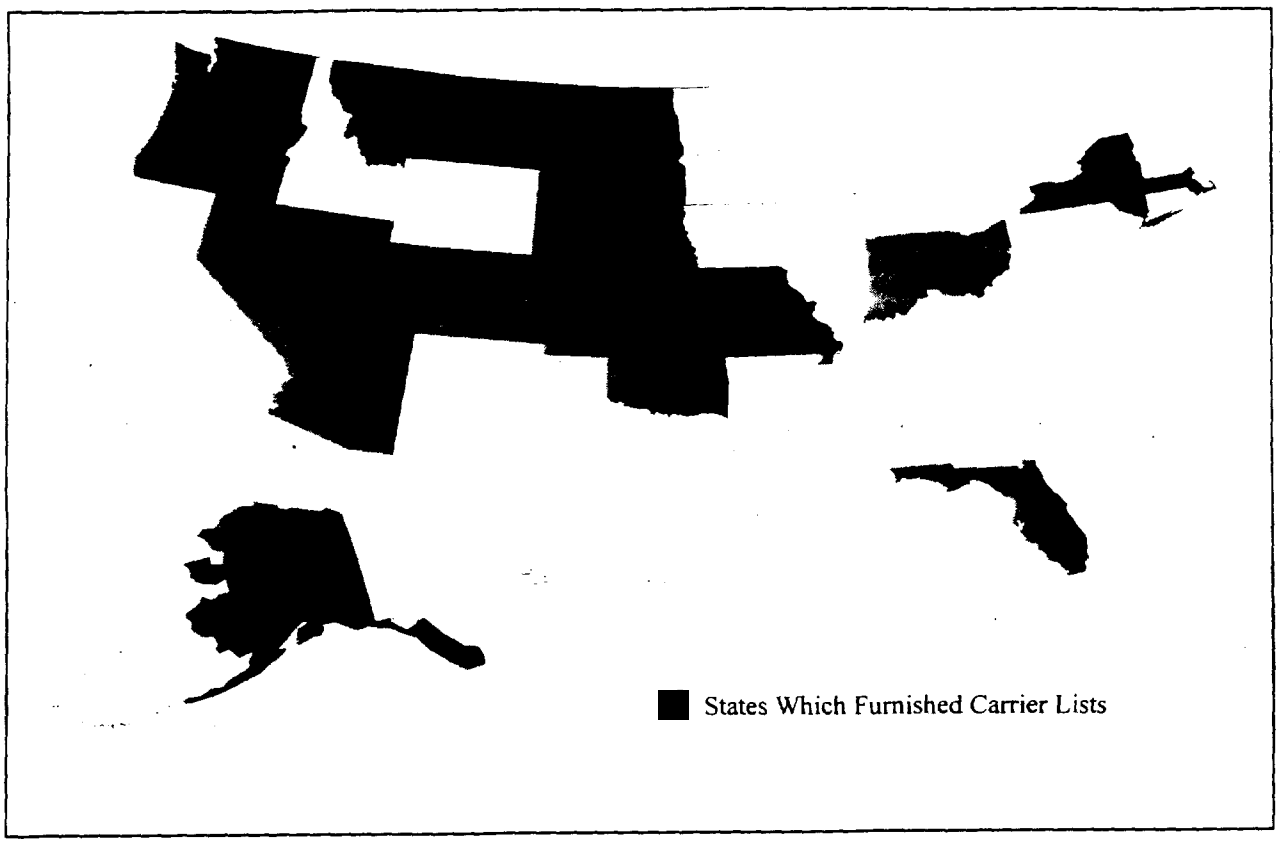

Figure 3. States furnishing lists of eligible carriers to FHWA.

The interstate carriers identified on a particular State list were not uniformly "domiciled" in that State, but may have simply possessed an LCV permit — or other special permit — from the State.[10] In fact, substantial numbers of carriers appeared on multiple State lists.

Scientex matched carrier name-and-address data on the 19 State-furnished lists against FHWA's *Motor Carrier Management Information System* (MCMIS) to identify the USDOT Number associated with each listed carrier. Next, a "duplicate" check by USDOT Number was performed so that carriers appearing on more than one State list showed up only once on the *Eligible Carrier Master Dataset.*

The *Eligible Carrier Master Dataset* contained the names, addresses, and telephone numbers associated with 930 unique commercial motor carriers. For the purposes of this study, these 930 carriers constituted the population against which the study sample was drawn.

[10] State of "domicile" refers to the State in which the motor carrier maintains its legal headquarters, i.e., its "principal place of business."

3.4 SAMPLING

Definition and application of the sampling plan used in this study is summarized below.

3.4.1 Sampling Approach

A *stratified systematic sampling plan* was used to "invite" carriers to participate in the study. Towards this end, the study population was categorized by two sets of stratification variables:

- Geographic location of *carrier domicile*, and
- Carrier *fleet size*.

The "carrier domicile" stratum consisted of (1) the States where the listed carriers were domiciled, and (2) geographic groups within each State as indicated by zip code. The "fleet size" stratum consisted of the following groups: 1-20 power units; 21-76 power units; 77-999 power units; 1,000 and more power units; and "unknown" number of power units. Carriers in the "unknown" group, after they were contacted, were moved to the "known" fleet size categories according to the number of power units they said they operated. Within each stratum, all carriers had equal probabilities of being selected.

Although carriers within each stratum were equally likely to be invited to participate, the decision to actually participate rested solely with the carriers. To this extent, the methodology involved a *self-selecting sampling plan*.[11]

Use of this approach, of course, begs the question: Did the self-selecting methodology bias the study findings and outcomes? In other words, did those carriers which chose not to participate in the study make their choices because they had "something to hide" — e.g., exceptionally poor safety records? Conversely, did the carriers which agreed to participate do so because they were unusually "comfortable" with their safety records? To address these concerns, a safety fitness analysis of study participants versus non-participants was conducted using data independently stored in FHWA's MCMIS database. As summarized in Section 4.2, this analysis revealed no differences between the safety posture of carriers who agreed to participate in the study and those who opted not to participate.

Representation may not be made that the lists of carriers furnished by the States actually comport with the universe of carriers operating LCV's — at least based on the analyses performed in this study. In other words, the findings of this study pertain only to the carrier population from which the sample was drawn.

[11] FHWA considered two alternatives to granting carriers complete discretion over whether they would participate in the study. One alternative was to compel carrier participation using FHWA's legal authority to conduct Carrier Compliance Reviews and other enforcement actions. The other was to request that industry trade groups formally encourage their members to participate. FHWA considered these alternatives, but rejected both, opting instead to make carrier participation in the study wholly voluntary.

3.4.2 Sampling Outcomes

Using a systematic sampling approach, attempts were made to contact a total of 711 carriers, or 76 percent of the 930 unique carriers in the study population. Of the 711 carriers, 27 percent could not be contacted, despite repeated attempts, using telephone numbers and carrier addresses in the MCMIS database; three percent of the carriers were determined to be out-of-business. An additional 25 percent of the 711 carriers did not appear "qualified" to participate in the study — i.e., the responses provided to the over-the-phone interviewer indicated that these carriers were not currently operating LCV's. Of the 711 carriers, 319 — or 45 percent — were determined to be eligible to participate in the study.

All 319 eligible carriers were invited to participate; of these, 77 carriers — or 24 percent of those asked to participate — agreed to take part. Those carriers opting not to participate most frequently said they were "too busy" or simply "not interested." Data furnished by two carriers had to be discarded, as the data were found to be unreliable or incomplete.

Fleet size distributions for the 75 LCV carriers providing usable information broke out as follows:

- 1-20 Power Units — 30 Carriers
- 21-75 Power Units — 25 Carriers
- 76-999 Power Units — 16 Carriers
- 1,000 Or More Power Units — 4 Carriers

Smaller carriers, by design, were over-represented in the study sample. This is because average VMT per carrier is considerably lower for smaller carriers than for larger carriers.

3.5 DATA VALIDATION

Various techniques and procedures to validate the study's data were tested and refined during a pretest of the methodology. Key validation procedures are summarized below.

3.5.1 General Procedures

Information and comments furnished by study participants were continuously monitored for *completeness* and *consistency*. For instance, edit checks in the data-collection software confirmed that estimated VMT subtotals by vehicle configuration matched total VMT reported by carriers. Similarly, logic checks were performed and anomalies flagged as appropriate — e.g., when a given carrier indicated that 100 percent of its travel occurred during daylight, even though one or more of its accidents was identified as occurring at night. Also, equipment inventories were examined to confirm that the carriers could support the vehicle configurations claimed (e.g., that a given carrier owned or leased trailers of sufficient length to configure Rocky Mountain Doubles).

Inconsistencies in information — most of which appeared to be inadvertent — were usually identified and clarified before the site visits ended. When inconsistencies in data were identified after the site visits were over, follow-up calls were made to the carriers furnishing the information in order to clarify the issues. In the two instances where inconsistencies in data could not be reconciled, all data for both carriers were discarded.

3.5.2 Verification of Accident Completeness

One methodological concern was whether carriers would truthfully identify all of their accidents to the Scientex Data-Collection Facilitator. Although it was not practical to verify, independently, all accident occurrences for every given carrier, selected accidents were, in fact, corroborated. FHWA's MCMIS database was used in the accident corroboration.

All accident records contained in MCMIS for a given carrier must, by definition, be identified in that carrier's Accident Register.[12] Therefore, during each site visit, comparisons between MCMIS and Accident Register records were made to confirm that (1) all incidents reported in MCMIS were also identified in the Accident Register, and (2) that the accident details in MCMIS matched those in the Accident Register. For only one carrier visited were the discrepancies between the two sets of accident records so extreme that all the data associated with that carrier had to be discarded.

3.5.3 Participant Versus Non-Participant Comparisons

Since carriers were at liberty to accept or reject the invitation to participate in the study, a comparative safety fitness analysis of study participants and non-participants was performed using data in the MCMIS database. The analysis compared violation and out-of-service violation rates for the two groups of carriers as measured during roadside driver-vehicle inspections.

As noted previously, the analysis of data revealed no differences between the safety posture of carriers who agreed to participate in the study and those who opted not to participate.

3.5.4 Assignment of Confidence Indices to VMT Estimates

Since computation of credible vehicle accident rates was central to the study's methodology, confidence in the mileage figures used to calculate the rates was critical. In almost all instances, carriers were able to supply precise and verifiable mileage figures for overall VMT experienced by their fleets. Many carriers were able to identify the specific VMT associated with LCV and Non-LCV travel; others, however, could only specify the approximate percent of their travel by, say, Rocky Mountain Doubles. On the most specialized questions — e.g., the percent of LCV travel on interstate versus arterial roads — respondents nearly always framed their estimates as a percent of total VMT.

Using a prescribed set of criteria, the Scientex Facilitator assigned a *reliability index* to each VMT estimate supplied by carriers. Allowable reliability scores ranged from "0" for *totally unreliable*

[12] The reverse is not always true — all incidents listed in the carrier's Accident Register are not necessarily identified in MCMIS.

data to "100" for *totally reliable data*. A score of "80" was assigned for *very reliable data*, and a score of "60" for *marginally reliable data*.

To be assigned a reliability score of "100," the following criteria had to be met: (1) the VMT data were observed to be extracted from specific carrier records; (2) the same data were supplied to one or more Government entities (e.g., tax offices); (3) the data were verifiable through alternative means; and (4) the data could be inspected by the Facilitator.

To be assigned a reliability score of "80," the following criteria had to be met: (1) the VMT data were observed to be extracted from specific carrier records; (2) the data were not necessarily verifiable through alternative means; (3) the carrier official supplying the data was intimately knowledgeable about the data and had no apparent motive for misrepresenting the data; and (4) the data could be inspected by the Facilitator.

To be assigned a reliability score of "60," the following criteria had to be met: (1) the VMT data were arrived at by applying estimation factors to data extracted from specific carrier records; (2) the estimation factors were predicated on rational assumptions; and (3) the carrier official supplying the data was intimately knowledgeable about the data, was qualified to arrive at the estimation factor, and had no apparent motive for misrepresenting the data.

Very few VMT estimates were assigned reliability scores below "60."

Applying the full range of criteria, the following general conclusions can be drawn about the reliability of VMT data supplied by study participants:

- Carrier estimates of total carrier VMT, total LCV VMT, and total Non-LCV VMT were 95-100 percent reliable.
- Carrier estimates of total VMT for individual vehicle configurations (Rocky Mountain Doubles, Turnpike Doubles, Triples, etc.) were 85-90 percent reliable.
- Carrier estimates of total LCV/Non-LCV VMT by external parameters (area, route, terrain, etc.) were 65-70 percent reliable.

The reliability of the various VMT data should be taken into account during review and interpretation of study findings.

3.6 STUDY EVENTS AND SEQUENCES

The study methodology consisted of the following activity sets:

- *Carrier recruitment*,
- *Data-collection*, and
- *Data-processing and data-analysis*.

These activities were pretested near the outset of the study, during site visits to five motor carriers.

3.6.1 Recruitment Procedures

Recruitment of eligible motor carriers to participate in the study entailed: (1) selecting candidate carriers; (2) contacting carriers; (3) furnishing carriers a *Study Information Overview*; (4) scheduling site visits; and (5) mailing carriers a *Site-Visit Packet*.

Select Candidate Carriers. Randomly-ordered lists of carriers, by fleet size, were generated for each geographic location. Carriers were then telephoned in the sequence listed. Telephoning within a given geographic jurisdiction continued until (1) the sample-size allotment for each location/fleet size group was satisfied, or (2) all carriers within the location/fleet size group had been contacted. Carriers were called at the telephone numbers listed in the MCMIS database; if phone numbers were not specified in the database, or the numbers did not seem to be working, Long-Distance Information was contacted for clarification. When there was no answer, up to five additional attempts were made to contact the carriers; these follow-up attempts were initiated on multiple days, at different times of the day.

Contact Carriers. The purpose of the initial telephone calls to carriers was to (1) identify appropriate points-of-contact, (2) assess carriers' eligibility to participate in the study, and (3) supply carriers with general information about the project. Screening questions were used to identify carrier officials or employees most knowledgeable about vehicle configurations used by the company, operational patterns and practices, vehicle and driver safety, and record-keeping. In these and subsequent conversations with the carriers' designated points-of-contact, additional questions were asked to determine whether individual carriers, in fact, utilized LCV's. LCV carriers were then advised of the general subject matter of the study, the types of data being collected, and approximate levels of effort required from study participants.

Furnish Information Overview to Carriers. A two-page *Study Information Overview* was faxed or mailed to the designated points-of-contact at eligible carriers. The information overview (1) described the project's data-collection methodology, (2) explained the study's confidentiality clause (i.e., that all data would remain confidential and absolutely no study data identifying individual motor carriers would be turned over to FHWA or other Government agency), and (3) specified a small honorarium to be paid to participating carriers as acknowledgement of the time and effort they were donating to this research.

Schedule Site Visits. Following distribution of the *Study Information Overview*, each candidate carrier was again telephoned to (1) secure its consent to participate in the study, (2) schedule site visits for specific days and times, and (3) identify the carrier staff who would participate in the site visits.

Mail Site-Visit Packet. Written confirmation of the dates and times for site visits was mailed to participating carriers. Included was a *Vehicle-Miles Data Sheet*, which carriers could, at their option, fill out prior to the site visits and thereby speed up the time required to complete the visits. The data

sheet allowed baseline VMT data, by vehicle configuration and highway conditions, to be researched and recorded in advance of the site visits.

3.6.2 Data-Collection Procedures

Data-collection consisted of the following primary activities: (1) reviewing baseline data about the carrier; (2) gathering demographic data; (3) collecting VMT data and assessing reliability; (4) collecting accident data; and (5) gathering qualitative information. All data were entered into a laptop computer; appropriate mechanisms were employed to prevent the accidental loss of data.

Review Baseline Data. Prior to the site visit, two sets of data were downloaded from the MCMIS database: (1) a Carrier Profile, which identified the carrier's primary operating characteristics and summarized its safety performance; and (2) a data "dump" of all accidents listed in the national database which occurred during the years covered by the study. Though some of the information proved to be out-of-date, the data did furnish the Scientex Facilitator with a basic portrait of the carrier. Also, the data served as a baseline against which the data and comments furnished by the carrier could be compared and evaluated.

Gather Carrier Demographics. At the outset of each site visit, a short Orientation Session was conducted. It was used, in part, to familiarize the carrier with the study's data-collection procedures. It was also used to gather descriptive information about carrier operations — e.g., carrier type, geographic areas where operating, fleet size, total equipment (power units and trailers), trailer lengths, LCV configurations operated, patterns of LCV operations, total drivers, driver experience, and descriptions of pertinent records maintained by the carrier.

Collect VMT Data. The Facilitator met with a senior official at the company — or other designated point-of-contact — to identify essential mileage patterns. Identification of VMT began at the most aggregated levels (e.g., overall VMT for a given year) and worked towards increasingly detailed breakouts (e.g., total VMT by vehicle configuration, followed by total VMT by vehicle configuration under specific conditions); not all carriers could provide the more detailed information. Also, investigations of VMT began with the most recent calendar year and worked backwards for a total of up to five years of data; again, not all carriers could furnish VMT data for the earlier years.

The Facilitator gauged the reliability of each VMT estimate (see Section 3.5.4). In general, estimates which were grounded in empirical data maintained by the carrier and shared with the Facilitator received higher scores than those which did not.

Collect Accident Data. The Scientex Facilitator requested access to records of all public-road accidents occurring during each year for which VMT data were available. Some carriers granted the Facilitator direct access to the Accident Register and other accident record sources. Most, however, chose to extract the requested records and information from the files, without allowing the Facilitator to access the files directly. The Facilitator used the MCMIS accident data to confirm that corresponding accident records presented by the carrier were complete and accurate.

The following data were collected for all accidents:

- Accident date and time.
- Accident location.
- Configuration of the commercial vehicle (i.e., LCV or Non-LCV), and
- Accident outcome (i.e., number of fatalities, number of injuries, and whether vehicles were towed away from the accident scene).

Additional data elements, captured when available, included: (1) LCV or Non-LCV vehicle type, (2) characteristics of the accident location (area, route, and terrain), (3) weather conditions at the time of the accident, (4) road surface conditions at the time of the accident, (5) driver's professional driving experience at the time of the accident, (6) driver's experience operating the vehicle configuration involved in the accident, and (7) miles into the trip driven at the time of the accident.

Gather Qualitative Information. At the conclusion of the site visit, the Facilitator conducted an exit interview with the carrier's senior official or other designated point-of-contact. The interview afforded the opportunity to (1) examine apparent discrepancies in the data, (2) identify additional information which the carrier was asked to make available to the Facilitator, and (3) examine key operating characteristics of LCV's. The latter topic was designed to move the discussion away from a strict focus on quantitative data and provide a forum in which carrier respondents, themselves, could comment on the operational and safety distinctions between LCV's and Non-LCV's. These comments, summarized in Section 4.6, may add a useful perspective to policy deliberations regarding LCV's.

3.6.3 Data-Processing and Data-Analysis

Data from each carrier site, initially stored on laptop computers, were loaded into a *Master LCV Database* created in *Paradox*. Final, specialized edit checks were performed on the data; every effort — including follow-up phone discussions with participating carriers — was made to eliminate data anomalies. In the several instances where anomalies could not be eliminated, the questionable data were deleted from the database and excluded from final analyses.

In analyzing the data, a broad range of extract procedures and queries were performed. In most instances, accident rates were calculated per million vehicle miles of travel. Regression analysis was used to assess the relationships between key study variables — notably LCV's and Non-LCV's — and accident experience. Differences in accident rates between LCV's and Non-LCV's were also calculated, and the standard error and confidence intervals associated with these differences were identified. All analyses were performed at a 95 percent confidence level.

General analyses of data were conducted by The Scientex Corporation. Specialized analyses were performed by the University of Michigan's Transportation Research Institute.

3.7 LIMITATIONS OF THE METHODOLOGY

The methodology employed in this study, like all research methodologies, had its strengths and limitations. Strengths of the methodology included the following:

- More comprehensive, nationwide data were able to be examined during this study than could have been had a short-term observational study been performed.
- Study data — collected directly from their sources, rather than from intermediate storehouses — reflect carriers' own firsthand experiences with LCV's.
- Study findings, compiled over multiple years, are predicated on real-world data, not synthetic experimental findings.

Yet the study's approach, for all its strengths, also had its limitations. Major limitations, summarized below, should be considered as the project's findings are reviewed and interpreted:

Study Findings Are Limited to Carriers Identified by the States. Carriers invited to participate in the study were drawn from lists furnished by the States. No independent assessment was made of the comprehensiveness of State lists — obviously, LCV carriers not identified on the State lists had no possibility of being selected. Also, since most of the State lists included carriers who were not necessarily LCV permit holders, respondents' assertions that they did not operate LCV's generally had to be taken at face value.

Findings Are Limited to LCV Carriers. Although the study compared LCV and Non-LCV accident rates, both sets of data were calculated from information furnished only by carriers operating LCV's. While this approach was needed to control for variations in carrier management techniques, etc., it had the effect of restricting study findings to current LCV carriers only. Indeed, as documented in Section 4.2, the population of LCV carriers from which the study sample was drawn was, on average, significantly safer than the U.S. carrier population at-large.

Carriers Could Decline to Participate in the Study. While study participants and non-participants were shown to possess comparable safety histories, the voluntary nature of participation may have influenced other factors, such as carrier representation by fleet size.

Carriers Self-Reported Their Data. The risk here pertains both to intentional and inadvertent bias. Even though most respondents appeared to be exceptionally adept at estimating detailed VMT, absolute validation of the numbers was not possible. Also, the quality of accident data was limited by the accuracy and thoroughness of carrier record-keeping. On the subject of driver experience, some carriers could only report length of driver employment with their companies, not total professional driving experience.

Study Definitions Had to Fit Existing Data Formats. Because the methodology for this study used existing records and formats, definitions of study terms could not be very precise. Participants had

to be able to "fit" the information they possessed to the study's terminology. Terms such as "rural" and "mountainous terrain" were not likely to be interpreted the same way by all participants.

Detailed Units of Analysis Were Likely to Be Less Reliable. As increasingly detailed information about carrier VMT was requested, the proportion of respondents able to supply the particular details decreased. Even when respondents did provide the detailed VMT, the reliability of the information was judged to be lower than when less detailed information was requested.

4.0 STUDY FINDINGS

This section of the report presents the study findings. It (1) describes the sample group, (2) compares the safety fitness of study participants and non-participants, (3) examines the general impact of vehicle configurations on accident rates and accident severity, (4) looks at the relationship between external factors and LCV/Non-LCV accident rates, and (5) summarizes the study's "anecdotal" data.

4.1 DESCRIPTION OF THE STUDY SAMPLE

Seventy-five commercial motor carriers, domiciled in 17 States, participated in the study; all 75 carriers operated both LCV's and Non-LCV's. Sixty-five percent of the participants were *for-hire* carriers, 15 percent were *private* carriers, and 20 percent were classified as *both for-hire and private* carriers. Participants accumulated a total of 2.8 billion vehicle miles of travel which were used in the study; this VMT correlated with 4,518 LCV and Non-LCV accidents. LCV travel represented 22 percent — or 612 million miles — of the total VMT.

Figure 4 shows the States of domicile for the participating carriers. In general, the two smallest groups of participants — Fleet Sizes 1-20 and 21-75 — tended to be small regional carriers with relatively narrow operational jurisdictions.[13] Carriers in Fleet Size 76-1,000 operated across broad sections of the country, particularly in Western and Midwestern States, but also in selected Eastern and Southeastern States. Carriers in Fleet Size 1,000+ operated in every State of the continental United States.

The study participants transported a wide range of commodities, including (1) general freight; (2) household goods; (3) building materials; (4) paper products; (5) dry-bulk commodities; (6) coal; (7) fresh produce; (8) livestock; (9) grain and feed; (10) meat; (11) refrigerated foods; (12) beverages; (13) metal; (14) logs, poles, and lumber; (15) machinery; (16) chemicals; and (17) liquids and gases. No meaningful differences in the types of commodities transported by LCV's versus those hauled by Non-LCV's were detected.

The mean numbers of power units and trailers — owned or leased — for each of the four fleet size groups are shown in Table 1.

Table 2 identifies, by fleet size, the number of study participants, total VMT, and total accidents. The data reveal that while carriers in Fleet Size 1-20 made up 40.0 percent of the study population, they contributed just 2.2 percent of the VMT and 1.6 percent of the accidents. This contrasts with carriers in Fleet Size 1,000+ which comprised only 5.3 percent of the population, but accrued 62.8 percent of the VMT and 63.6 percent of the accidents.

[13] Collectively, these smaller carriers frequented the following States: California, Colorado, Florida, Idaho, Illinois, Kansas, Missouri, Montana, Nevada, New York, Utah, Washington, Wisconsin, and Wyoming.

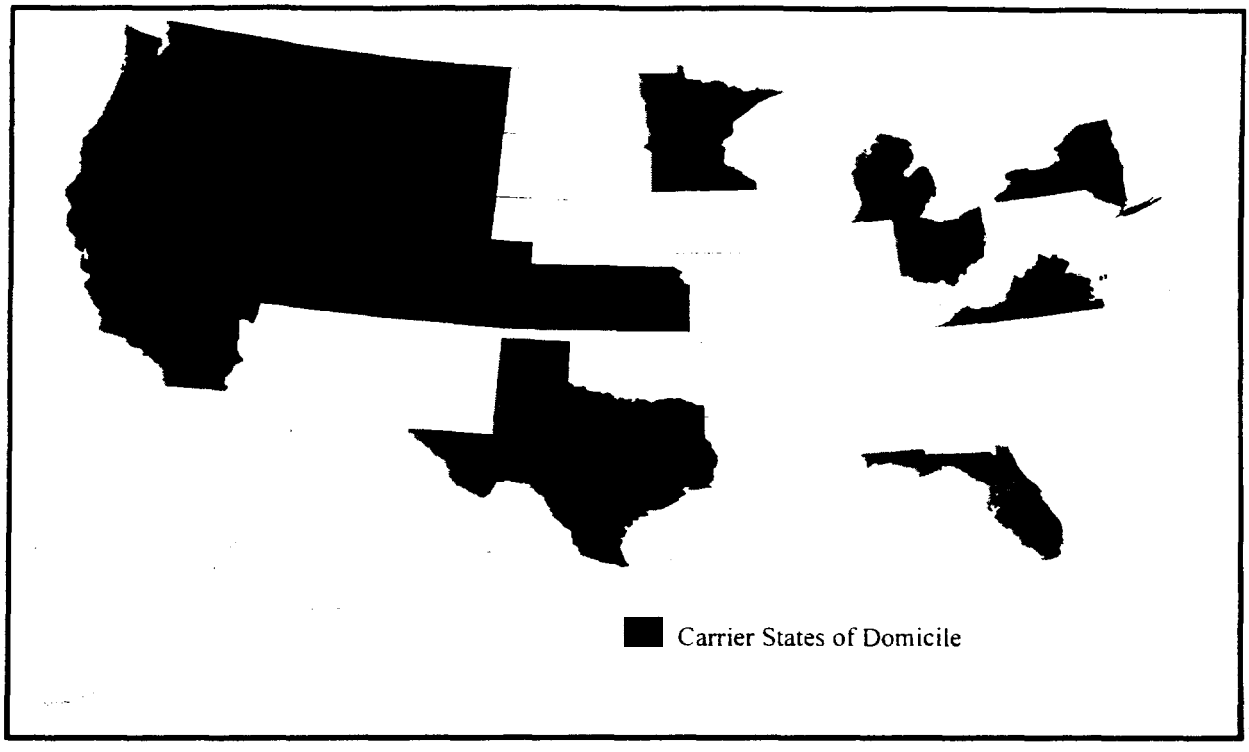

Figure 4. States of domicile of study participants.

Table 1. Power units and trailers by fleet size: mean number per carrier.

Fleet Size	Mean Power Units	Mean Trailers
≤20	8	24
21-75	42	85
76-999	221	289
≥1000	16,936	50,254

The distribution of VMT among some of the study's external factors — area, route, terrain, and time-of-day — is summarized in Figure 5; percentages shown represent both LCV and Non-LCV travel. Seventy-four percent of the total VMT accumulated by participating carriers occurred in rural areas, 66 percent on arterial roads, 71 percent on level terrain, and 52 percent during the night. Figure 6 summarizes the distribution of professional driving experience among the participating carriers. Ten percent of the drivers were reported to have had less than one year of experience, whereas 39 percent of the drivers had seven or more years experience.

Table 2. Participants, VMT, and accidents by fleet size.

	≤20	21-75	76-999	≥1000	Total
Number of Participants	30	25	16	4	75
Percent	40.0%	33.3%	21.3%	5.3%	100.0%
Total VMT (in thousands)	63,611	329,175	664,060	1,784,038	2,840,884
Percent	2.2%	11.6%	23.4%	62.8%	100.0%
Total Accidents	71	441	1,134	2,872	4,518
Percent	1.6%	9.8%	25.1%	63.6%	100.0%

4.2 COMPARISONS BETWEEN POPULATIONS

Safety fitness comparisons among two distinct population sets are summarized below: (1) *study participants versus non-participants*, and (2) *study versus national populations*. The groups comprising the population sets are defined as follows:

- ***Study Participants.*** Those carriers which accepted the invitations to participate in the LCV research.
- ***Study Non-Participants.*** Those carriers invited to participate in the research, but who declined the invitations.
- ***Study Population.*** Those carriers eligible to participate in the research, i.e., study participants and non-participants combined.
- ***National Population.*** All commercial carriers identified by FHWA as operating in U.S. interstate commerce.

Data for these comparisons were drawn from FHWA's *1994 MCMIS Inspection Database*, which contains the results of 1.4 million driver-vehicle safety inspections. Inspection records in MCMIS identify the number of individual "violations" of the *Federal Motor Carrier Safety Regulations* and *Hazardous Materials Regulations*; the most severe violations are termed "out-of-service (OOS) violations" and require that the vehicles or drivers be placed out-of-service. The "violation rate" for a single carrier, or a specified group of carriers, is the mean number of violations experienced per 100 inspections.

A strong statistical correlation between violation rates and carrier safety fitness has long been demonstrated — for example, carriers with high violation rates tend to exhibit poor safety performance.

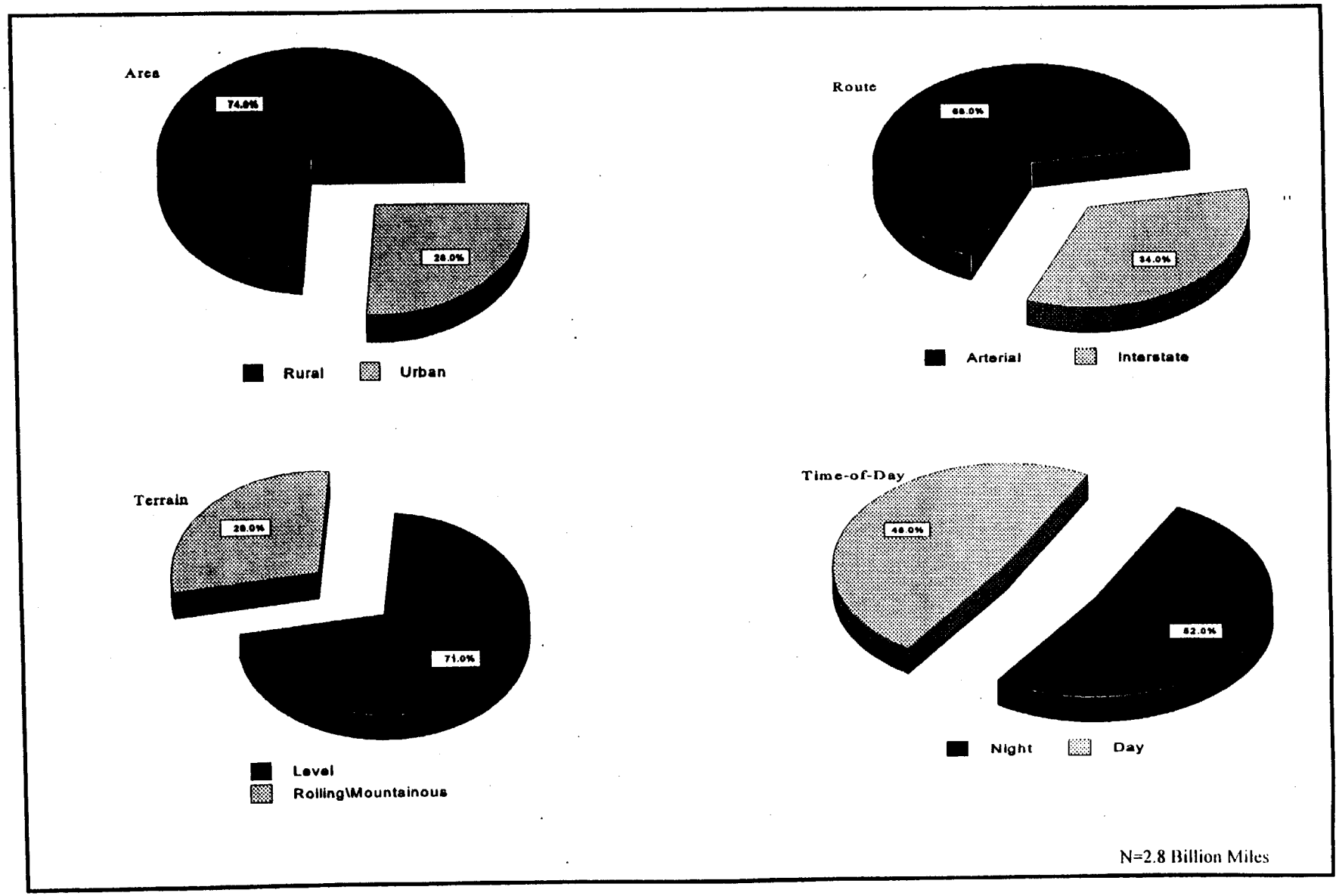

Figure 5. Distribution of VMT among study participants by external factors.

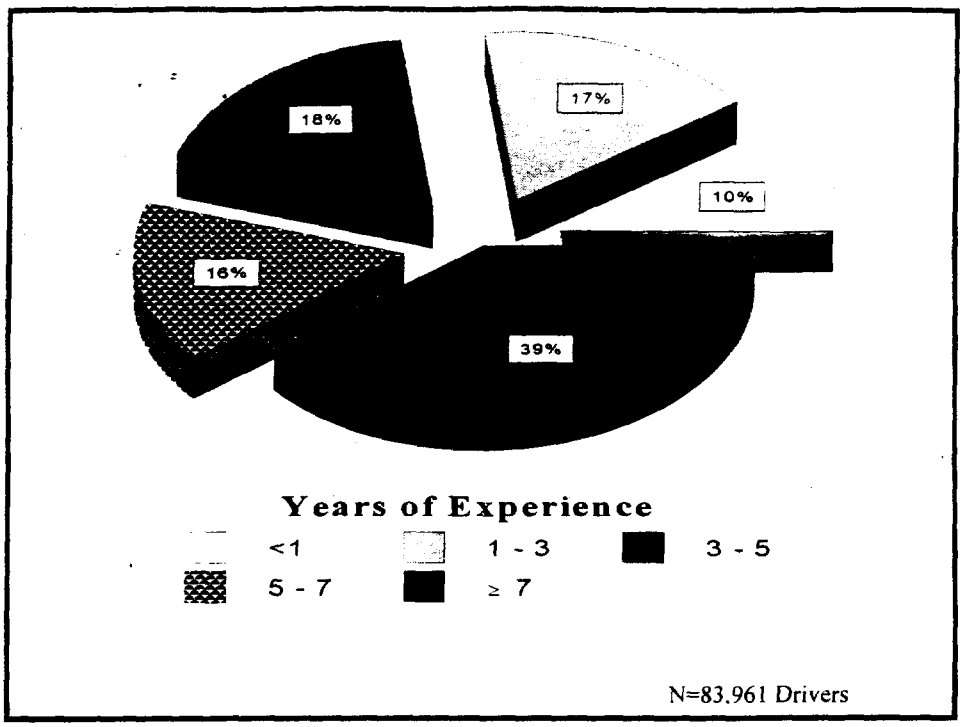

Figure 6. Distribution of drivers by years of professional experience.

4.2.1 Participants Versus Non-Participants

Figure 7 compares violation and OOS violation rates for study participants and non-participants. Rates for the two groups were substantially the same; in 1994, study participants experienced 4.3 percent more violations — but 9.1 percent fewer OOS violations — than study non-participants. These differences are not significant and strongly suggest that the research results were not biased by carrier refusal to participate. In other words, had the non-participants contributed their data to this research, it is reasonable to expect that the study results would still have been substantially the same.

4.2.2 Study Versus National Populations

Figure 8 compares violation and OOS violation rates for the study and national populations. Here the differences are significant: the carrier population at-large experienced 46.7 percent more violations — and 50.0 percent more OOS violations — than did the study population. These results indicate that the population of carriers currently operating LCV's possesses a safety fitness record far superior to that of the general carrier population. Readers, consequently, should be cautious about using this study's findings to predict future LCV safety performance in the event that current restrictions on LCV operations are modified or lifted.

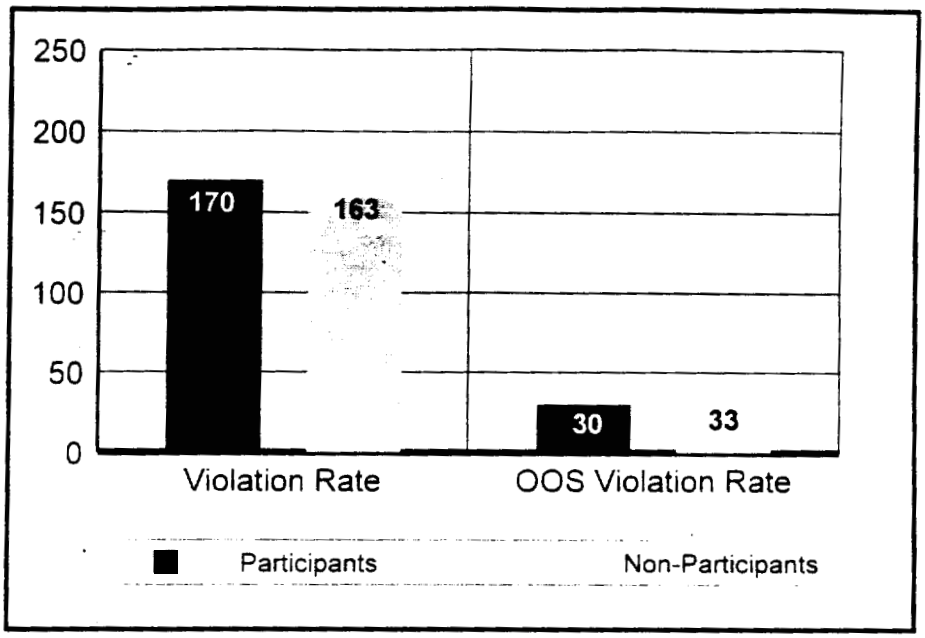

Figure 7. Study participants versus non-participants: violations per 100 driver-vehicle inspections (MCMIS, 1994).

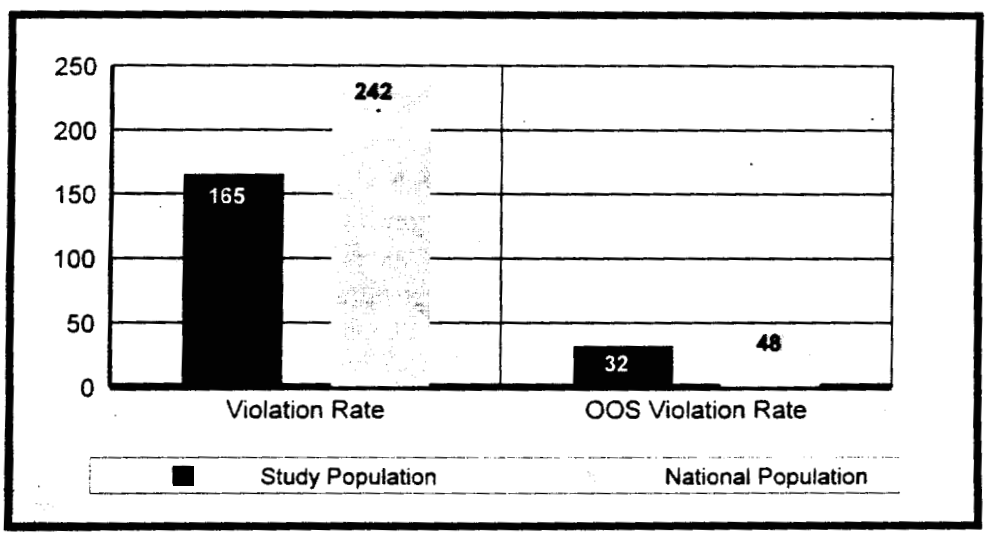

Figure 8. Study population versus national carrier population: violations per 100 driver-vehicle inspections (MCMIS, 1994).

4.3 IMPACT OF VEHICLE CONFIGURATION ON ACCIDENT RATES

4.3.1 LCV's Versus Non-LCV's

For the carrier population studied, the accident rate for LCV's was approximately 50 percent lower than the accident rate for Non-LCV's; the difference in rates was statistically significant. There were also differences in rates among the individual vehicle configurations comprising the LCV group, but these differences were not found to be statistically significant.

Mileage and Accident Data. Figure 9 compares the proportions of total miles travelled and accidents experienced by LCV's and Non-LCV's. Seventy-nine percent of the miles travelled by study participants were accrued by Non-LCV's, even though Non-LCV's experienced a disproportionate 88 percent of total accidents. Conversely, LCV's accumulated 22 percent of the VMT, but experienced only 12 percent of the accidents. Breakdowns of VMT and accidents for individual LCV and Non-LCV configurations are summarized in Tables 3 and 4, respectively. Of note, Tractors-Semitrailers accrued 31 percent of the travel, but experienced 37 percent of the accidents. LCV Doubles, on the other hand, accumulated 11 percent of the VMT, but experienced 7 percent of the crashes; Triples accrued 10 percent of all VMT, but were involved in only 5 percent of all accidents.

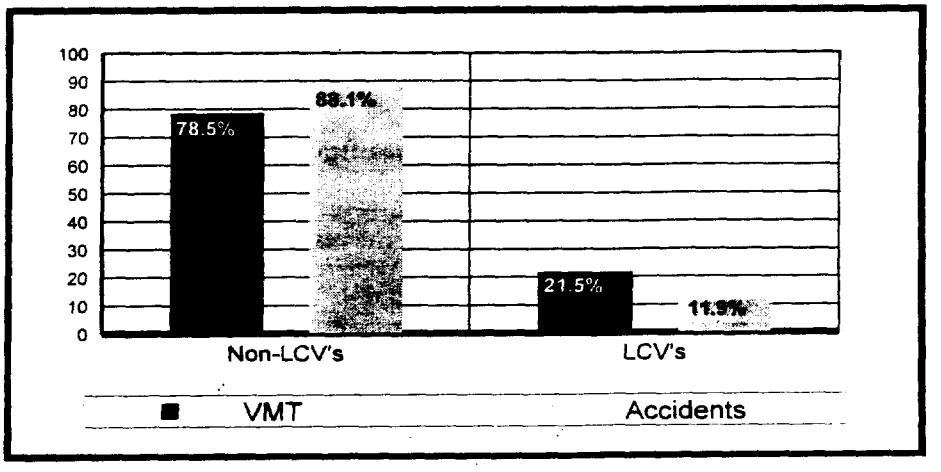

Figure 9. Percentage of VMT and accidents: LCV's versus Non-LCV's.

Accident Rates Between Groups. Figure 10 summarizes differences in accident rates between LCV's and Non-LCV's. Among study participants, the accident rate was 1.79 per million VMT for Non-LCV's versus 0.88 for LCV's. In other words, Non-LCV's were more than twice as likely as LCV's to be involved in accidents. The difference in rates between the two groups was statistically significant.

Table 3. Vehicle miles of travel by configuration.

Configuration	VMT (In thousands)	% of Total VMT
Singles (Tractors-Semitrailers)	867,553	30.5%
STAA Doubles (≤80,000 lbs)	1,361,666	47.9%
Total Non-LCV's	**2,229,219**	**78.5%**
STAA Doubles (>80,000 lbs)	17,620	0.6%
Rocky Mountain Doubles	225,456	7.9%
Turnpike Doubles	75,316	2.7%
Total LCV Doubles	***318,392***	***11.2%***
Triples	288,367	10.2%
Other LCV's	4,906	0.2%
Total LCV's	**611,665**	**21.5%**
Total All Vehicles	**2,840,884**	**100.0%**

Table 4. Accidents by configuration.

Configuration	Accidents	%
Singles (Tractors-Semitrailers)	1,671	37.0%
STAA Doubles (≤80,000 lbs)	2,311	51.2%
Total Non-LCV's	**3,982**	**88.1%**
STAA Doubles (>80,000 lbs)	39	0.9%
Rocky Mountain Doubles	178	3.9%
Turnpike Doubles	77	1.7%
Total LCV Doubles	***294***	***6.5%***
Triples	239	5.3%
Other LCV's	3	0.1%
Total LCV's	**536**	**11.9%**
Total All Vehicles	**4,518**	**100.0%**

Table 5 shows the accident rate, standard error, and confidence intervals for each LCV and Non-LCV subgroup examined in the study; data are shown at a 95 percent confidence level, meaning there was a 95 percent likelihood that the accident rate for any given carrier among the study population would not deviate from the mean accident rate for all carriers by more than approximately 2.0 times the standard error. For example, while the mean accident rate for Non-LCV's was 1.79,

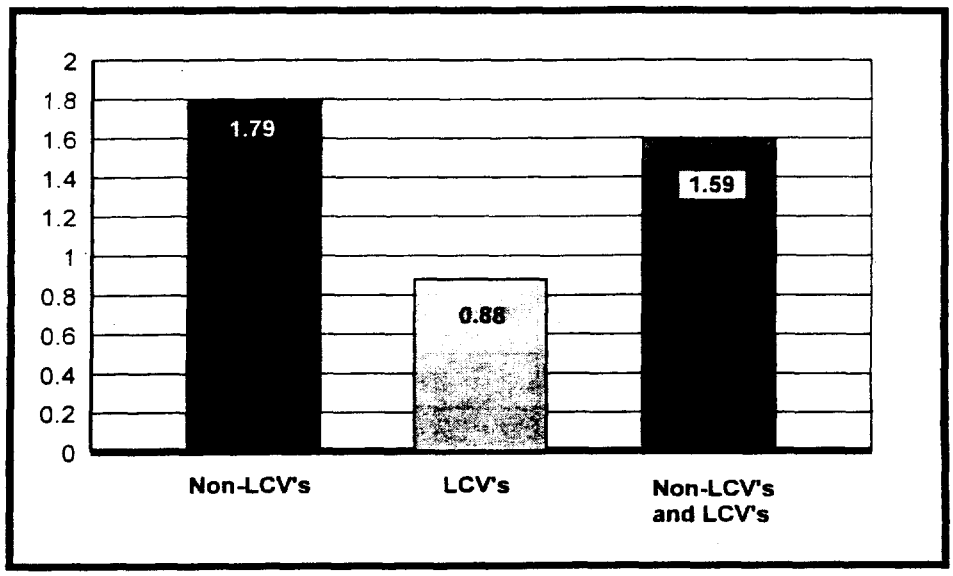

Figure 10. LCV versus Non-LCV accident rates: accidents per million VMT.

it could be expected — with 95 percent confidence — that the Non-LCV rate for a given carrier would fall between 1.52 and 2.06 accidents per million VMT. Similarly, while the mean accident rate for LCV's was 0.88, it could be expected — again with 95 percent confidence — that the LCV accident rate for a given carrier would fall between 0.51 and 1.25 accidents per million VMT.

It is instructive to examine the "difference" between the Non-LCV and LCV accident rates, as shown at the bottom of the table. In this study, the mean LCV accident rate was 0.91 less than the Non-LCV rate, with a standard error of 0.19. In other words, for any given pair of LCV and Non-LCV accident rates among the study population, the LCV accident rate — at least 95 percent of the time — would be between 0.54 and 1.28 accidents per million VMT lower than the Non-LCV rate.[14]

In summary, these observations indicate that among the study population, there were strong, statistical differences between the accident rates of LCV's and Non-LCV's, and that the LCV accident rate was consistently lower than the Non-LCV rate.

[14] Another way to compare LCV and Non-LCV accident performance is to examine the ratio of the LCV accident rate to the Non-LCV rate. Table 5, in fact, shows that the mean ratio is 0.49 and that, in 95 percent of all cases, the LCV accident rate would be expected to be between 30 and 70 percent of the Non-LCV rate.

Table 5. Accident rates by vehicle configuration: accidents per million VMT. (Confidence level: 95%)

Configuration	Accident Rate	Standard Error	Confidence Interval
Singles (Tractors-Semitrailers)	1.93	0.34	1.26 - 2.60
STAA Doubles (≤80,000 lbs)	1.70	0.16	1.39 - 2.01
Total Non-LCV's	**1.79**	**0.14**	**1.52 - 2.06**
STAA Doubles (>80,000 lbs)	2.21	0.80	0.64 - 3.78
Rocky Mountain Doubles	0.79	0.15	0.50 - 1.08
Turnpike Doubles	1.02	0.39	0.26 - 1.78
Total LCV Doubles	***0.92***	***0.15***	***0.51 - 1.25***
Triples	0.83	0.39	0.07 - 1.59
Other LCV's	0.61	0.64	0.00 - 1.86
Total LCV's	**0.88**	**0.19**	**0.51 -1.25**
Total All Vehicles	**1.59**	**0.15**	**1.30 - 1.88**
Ratio of LCV to Non-LCV Rates	**0.49**	**0.10**	**0.29 - 0.69**
Difference Between LCV and Non-LCV Rates	**0.91**	**0.19**	**0.54 - 1.28**

Accident Rates Within Groups. The accident experience of individual vehicle configurations within the LCV and Non-LCV groups may also be compared. Table 5 shows, for example, that among the standard LCV configurations, Rocky Mountain Doubles had the lowest accident rate (0.79), whereas among all vehicle configurations, STAA Doubles Over 80K had the highest rate (2.21). Indeed, the accident rate for STAA Doubles Over 80K was 2.8 times that of Rocky Mountain Doubles and 2.2 times the rate for Turnpike Doubles. Overall, the accident rate for LCV Doubles was 0.92, as compared to **0.83** for Triples.

Now, it is tempting to review these data and conclude, among other things, that Rocky Mountain Doubles were safer than Turnpike Doubles, that STAA Doubles Over 80K were inherently unsafe, etc. Such conclusions would be erroneous, however, in the absence of tests for statistical significance. To determine whether the intragroup standings were statistically significant, differences in accident rates between individual vehicle configurations and all other configurations were examined; the results are presented in Table 6. For instance, to compare Turnpike Doubles and Rocky Mountain Doubles (Table 6-5), the difference in mean accident rates was calculated (1.02 - 0.79 = 0.23), and the standard error (0.21) and confidence interval (-0.18 to +0.64) were computed as well. Since the confidence interval was, at once, both positive and negative, it was necessary to

Table 6. Differences in accident rates among LCV and Non-LCV configurations. (Confidence level: 95%)

6-1. Differences in accident rates between Singles (Tractors-Semitrailers) and other vehicle configurations.

Configuration	Accident Rate Difference	Standard Error	Confidence Interval
STAA Doubles (≤80,000 lbs)	0.22	0.40	(0.56) - 1.00
STAA Doubles (>80,000 lbs)	-0.29	0.72	(1.70) - 1.12
Rocky Mountain Doubles	1.14	0.37	0.41 - 1.87
Turnpike Doubles	0.90	0.35	0.21 - 1.59
Triples	1.10	0.46	0.20 - 2.00
Other LCV's	1.31	0.68	(0.02) - 2.64

6-2. Differences in accident rates between STAA Doubles (≤80,000 lbs) and other vehicle configurations.

Configuration	Accident Rate Difference	Standard Error	Confidence Interval
Singles (Tractors-Semitrailers)	-0.22	0.40	(1.00) - 0.56
STAA Doubles (>80,000 lbs)	-0.51	0.77	(2.02) - 1.00
Rocky Mountain Doubles	0.91	0.21	0.50 - 1.32
Turnpike Doubles	0.67	0.21	0.26 - 1.08
Triples	0.87	0.38	0.13 - 1.61
Other LCV's	1.09	0.69	(0.26) - 2.44

6-3. Differences in accident rates between STAA Doubles (>80,000 lbs) and other vehicle configurations.

Configuration	Accident Rate Difference	Standard Error	Confidence Interval
Singles (Tractors-Semitrailers)	0.29	0.72	(1.12) - 1.70
STAA Doubles (≤80,000 lbs)	0.51	0.77	(1.00) - 2.02
Rocky Mountain Doubles	1.42	0.78	(0.11) - 2.95
Turnpike Doubles	1.19	0.76	(0.30) - 2.68
Triples	1.38	0.85	(0.29) - 3.05
Other LCV's	1.60	0.96	(0.28) - 3.48

6-4. Differences in accident rates between Rocky Mountain Doubles and other vehicle configurations.

Configuration	Accident Rate Difference	Standard Error	Confidence Interval
Singles (Tractors-Semitrailers)	-1.14	0.37	(1.87) - (0.41)
STAA Doubles (≤80,000 lbs)	-0.91	0.21	(1.32) - (0.50)
STAA Doubles (>80,000 lbs)	-1.42	0.78	(2.95) - 0.11
Turnpike Doubles	-0.23	0.21	(0.64) - 0.18
Triples	- 0.04	0.42	(0.86) - 0.78
Other LCV's	0.18	0.60	(1.00) - 1.36

Table 6 (Cont'd.). Difference in accident rates among LCV and Non-LCV configurations. (Confidence level: 95%)

6-5. Differences in accident rates between Turnpike Doubles and other vehicle configurations.			
Configuration	**Accident Rate Difference**	**Standard Error**	**Confidence Interval**
Singles (Tractors-Semitrailers)	-0.90	0.35	(1.59) - (0.21)
STAA Doubles (≤80,000 lbs)	-0.67	0.21	(1.08) - (0.26)
STAA Doubles (>80,000 lbs)	-1.19	0.76	(2.68) - 0.30
Rocky Mountain Doubles	0.23	0.21	(0.18) - 0.64
Triples	0.19	0.42	(0.63) - 1.01
Other LCV's	0.41	0.60	(0.77) - 1.59
6-6. Differences in accident rates betweenTriples and other vehicle configurations.			
Configuration	**Accident Rate**	**Standard Error**	**Confidence**
Singles (Tractors-Semitrailers)	-1.10	0.46	(2.00) - (0.20)
STAA Doubles (≤80,000 lbs)	-0.87	0.38	(1.61) - (0.13)
STAA Doubles (>80,000 lbs)	-1.38	0.85	(3.05) - 0.29
Rocky Mountain Doubles	0.04	0.42	(0.78) - 0.86
Turnpike Doubles	-0.19	0.42	(1.01) - 0.63
Other LCV's	0.22	0.69	(1.13) - 1.57
6-7. Differences in accident rates between Other LCV's and other vehicle configurations.			
Configuration	**Accident Rate**	**Standard Error**	**Confidence**
Singles (Tractors-Semitrailers)	-1.31	0.68	(2.64) - 0.02
STAA Doubles (≤80,000 lbs)	-1.09	0.69	(2.44) - 0.26
STAA Doubles (>80,000 lbs)	-1.60	0.96	(3.48) - 0.28
Rocky Mountain Doubles	-0.18	0.60	(1.36) - (1.00)
Turnpike Doubles	-0.41	0.60	(1.59) - 0.77
Triples	-0.22	0.69	(1.57) - 1.13

conclude that the difference in accident rates between Turnpike Doubles and Rocky Mountain Doubles was *not* significant.[15] In other words, even though the mean accident rate for Rocky

[15] The difference in mean accident rates between Turnpike Doubles and Rocky Mountain Doubles was 0.23 accidents per million VMT, with Turnpike Doubles having the higher mean rate. The confidence interval, extending from -0.18 to +0.64, indicated that individual accident rates for Rocky Mountain Doubles could be lower — but also sometimes higher — than the accident rates for Turnpike Doubles. No consistent pattern, then, could be discerned regarding the relationship between the accident rates of Turnpike Doubles and Rocky Mountain Doubles — hence the lack of statistical significance. Contrast this with the previous observations in which, in at least 95 percent of all occurrences, the LCV accident rate was expected to be lower than the Non-LCV rate.

Mountain Doubles was lower than the mean rate for Turnpike Doubles, there was not sufficient evidence available to determine that Turnpike Doubles were more prone to accidents than were Rocky Mountain Doubles.

In fact, the data in Table 6 show that, in nearly every instance, the differences in accident rates for individual configurations within the LCV and Non-LCV groups were not statistically meaningful. That is to say, observed differences in accident rates between Rocky Mountain Doubles and Turnpike Doubles — or between LCV Doubles and Triples — could not be definitively attributed to the configuration of these vehicles. On the other hand, the data do support the contention that the accident rates for individual Non-LCV configurations (i.e., Tractors-Semitrailers and STAA Doubles Under 80K) were statistically different from the major LCV configurations (i.e., Rocky Mountain Doubles, Turnpike Doubles, and Triples).

4.3.2 Patterns by Fleet Size

In this study, LCV and Non-LCV accident rates did, in fact, vary markedly by carrier fleet size. The differences, however, were neither consistent nor coherent; the expected relationship between fleet size and accident rates — that accident rates go down as fleet size goes up — was not at all evidenced by the data. The general pattern, however, that the LCV accident rate was lower than the Non-LCV rate held up across all fleet sizes.

Mileage and Accident Data. Figure 11 compares the proportions of LCV miles travelled and LCV accidents experienced by carriers in each of the four fleet size strata. Among study participants, LCV travel, as a percentage of total VMT, ranged from a low of 16 percent for those carriers operating 1,000 or more power units, to a high of 50 percent for those with 21-75 power units. In every instance, the percentage of LCV travel exceeded the percentage of LCV accidents, although

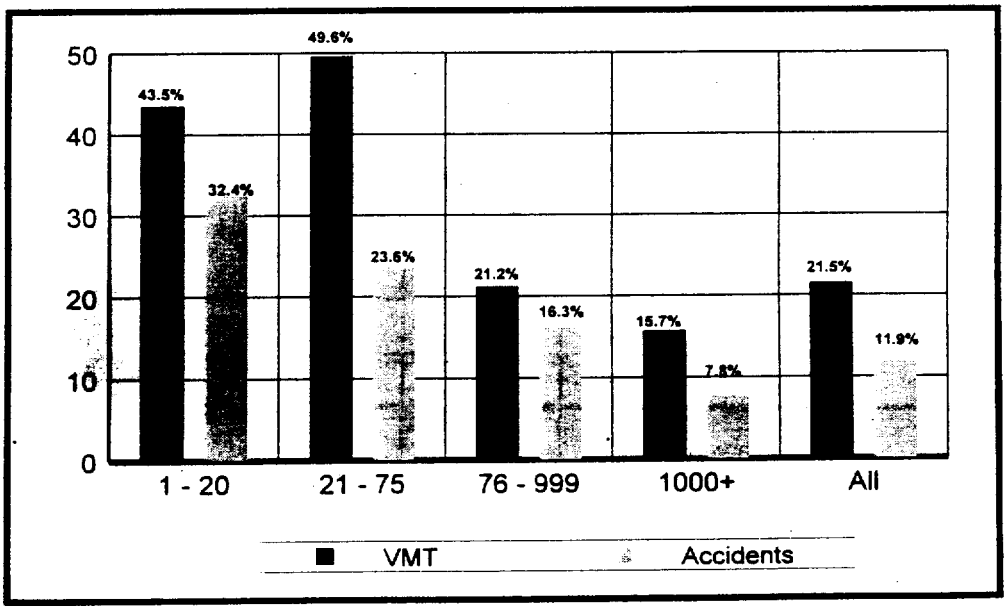

Figure 11. Percentage of LCV VMT and LCV accidents by fleet size.

the magnitude of the gap varied from one fleet size stratum to another. For example, among carriers with 76-999 power units, LCV's accumulated 21 percent of the VMT, but experienced 16 percent of the accidents; among carriers with 21-75 power units, LCV's accrued 50 percent of the travel, but experienced only 24 percent of total accidents.

Tables 7 and 8 show VMT and accidents, respectively, by vehicle configuration and fleet size. Table 7 reports the individual values as a percent of total VMT for each of the fleet sizes; Table 8 displays the actual counts of accidents.

Accident Rates. Table 9 shows accident rates by vehicle configuration and fleet size. Of the four fleet size groups, the lowest mean LCV accident rate (0.64) was achieved by carriers operating 21-75 power units; this contrasts with the Non-LCV accident rate, where the lowest rate (1.34) was attained by carriers with 20 or fewer power units. The highest overall LCV accident rate (1.31) was calculated for those carriers operating 76-999 power units.

The bottom row in Table 9 further examines the relationship between LCV and Non-LCV accident rates. In the total population, the LCV accident rate averaged 49 percent of the Non-LCV rate. But among the different fleet size groups, the averages varied broadly — from a low of 32 percent for carriers with 21-75 power units, to a high of 72 percent for carriers with 76-999 power units.

Table 7. Vehicle miles of travel (VMT) by configuration and fleet size: percentage of fleet size VMT.

	Fleet Size				
Configuration	**≤20**	**21-75**	**76-999**	**≥1,000**	**All Carriers**
Singles (Tractors-Semitrailers)	56.2%	43.0%	59.[illegible]%	16.5%	30.5%
STAA Doubles (≤80,000 lbs.)	0.3%	7.4%	19.[illegible]%	67.8%	47.9%
Total Non-LCV's	**56.5%**	**50.4%**	**78.8%**	**84.3%**	**78.5%**
STAA Doubles (>80,000 lbs.)	2.9%	0.6%	2.1%	0.0%	0.6%
Rocky Mountain Doubles	30.5%	43.8%	8.6%	0.2%	7.9%
Turnpike Doubles	7.9%	3.1%	8.1%	0.3%	2.7%
Total LCV Doubles	***41.4%***	***47.6%***	***18.8%***	***0.6%***	***11.2%***
Triples	0.8%	1.5%	2.0%	15.1%	10.2%
Other LCV's	1.4%	0.4%	0.4%	0.0%	0.2%
Total LCV's	**43.5%**	**49.6%**	**21.2%**	**15.7%**	**21.5%**
Total VMT for All Vehicles *(in thousands)*	**63,611**	**329,175**	**664,060**	**1,784,038**	**2,840,884**

Table 8. Accidents by configuration and fleet size.

	Fleet Size				
Configuration	**≤20**	**21-75**	**76-999**	**≥1,000**	**All Carriers**
Singles (Tractors-Semitrailers)	48	276	773	574	1,671
STAA Doubles (≤80,000 lbs.)	0	61	176	2,074	2,311
Total Non-LCV's	**48**	**337**	**949**	**2,648**	**3,982**
STAA Doubles (> 80,000 lbs.)	1	0	38	NA	39
Rocky Mountain Doubles	18	86	74	0	178
Turnpike Doubles	4	10	63	0	77
Total LCV Doubles	***23***	***96***	***175***	***0***	***294***
Triples	0	5	10	224	239
Other LCV's	0	3	0	NA	3
Total LCV's	**23**	**104**	**185**	**224**	**536**
Total All Vehicles	**71**	**441**	**1,134**	**2,872**	**4,518**

Table 9. Accident rates by configuration and fleet size: accidents per million VMT.

	Fleet Size				
Configuration	**≤20**	**21-75**	**76-999**	**≥ 1,000**	**All Carriers**
Singles (Tractors-Semitrailers)	1.34	1.95	1.95	1.95	1.93
STAA Doubles (≤80,000 lbs)	0.00	2.51	1.39	1.76	1.70
Total Non-LCV's	**1.34**	**2.03**	**1.81**	**1.76**	**1.79**
STAA Doubles (>80,000 lbs.)	0.54	0.00	2.79	NA	2.21
Rocky Mountain Doubles	0.93	0.60	1.29	0.00	0.79
Turnpike Doubles	0.79	0.97	1.17	0.00	1.02
Total LCV Doubles	***0.87***	***0.61***	***1.40***	***0.00***	***0.92***
Triples	0.00	0.99	0.74	0.83	0.83
Other LCV's	0.00	2.55	0.00	NA	0.61
Total LCV's	**0.83**	**0.64**	**1.31**	**0.80**	**0.88**
Total All Vehicles	**1.12**	**1.34**	**1.71**	**1.61**	**1.59**
LCV Accident Rate as Percentage of Non-LCV Rate	**61.9%**	**31.5%**	**72.4%**	**45.5%**	**49.2%**

Statistical Significance. The patterns apparent in Table 9 are scrutinized more fully in Table 10. There, the differences in LCV and Non-LCV accident rates, and the standard errors and confidence intervals associated with these rates, are compared by fleet size. Statistical significance was clearly demonstrated for two of the fleet size strata: carriers with 21-75 power units and carriers with 1,000 or more power units. Though not formally demonstrated for the other two strata, the general pattern that the LCV accident rate was considerably lower than the Non-LCV rate persisted; also, the difference in the aggregate accident rate (0.91) fell well within the confidence intervals of all four strata. Hence, it is reasonable to conclude that there were relatively consistent differences between the LCV and Non-LCV accident rates, regardless of fleet size.

4.3.3 Fatal and Injury Accidents

LCV's and Non-LCV's were nearly equally likely to be involved in fatal accidents. LCV's, however, were much less likely to be involved in injury accidents.

Accident Classes and Rates. The accidents identified by study participants were grouped into three classes, as follows:

- *Fatal Accidents.* Includes all accidents for which at least one fatality was reported. These accidents may also have involved non-fatal injuries and property damage.

- *Fatal-and-Injury Accidents.* Includes all fatal accidents, plus all other accidents involving at least one injury. Property damage may also have been a consequence of "fatal-and-injury" accidents.

- *All Accidents.* Includes all fatal-and-injury accidents, plus all other accidents which resulted in damage to property. "Property damage" accidents may or may not have involved vehicles being towed from the accident scene.

Table 11 shows the distributions of LCV and Non-LCV crashes among the three accident classes. Table 12 identifies the mean accident rate, by vehicle configuration, for fatal and fatal-and-injury accidents. According to the data, the probability of a fatal crash was nearly twice as high for Turnpike Doubles as for Rocky Mountain Doubles; the probability of involvement in fatal crashes was almost 4.5 times higher for LCV Doubles than for Triples.

Statistical Significance. Table 13 compares differences in LCV and Non-LCV accident rates for fatal accidents and fatal-and-injury accidents. While the overall probability of a fatal accident occurring was extremely small for both groups (just 0.02 accidents per million VMT), it appears, at first glance, that fatal accidents had a slightly greater probability of happening when Non-LCV's were involved. However, examination of the standard error and associated confidence intervals indicates that the rate differential was not statistically significant. At best, it can be concluded that LCV's and Non-LCV's had nearly equal probabilities of involvement in fatal crashes.

Table 10. Differences in LCV and Non-LCV accident rates by fleet size. (Confidence level: 95%)

Fleet Size (1-20)			
	Accident Rate	Standard Error	Confidence Interval
Non-LCV's	1.34	0.49	0.38 - 2.30
LCV's	0.83	0.27	0.30 - 1.36
Ratio of LCV to Non-LCV Rates	0.62	0.31	0.01 - 1.23
Difference Between LCV and Non-LCV Rates	0.50	0.57	(0.62) - 1.62
Fleet Size (21-75)			
	Accident Rate	Standard Error	Confidence Interval
Non-LCV's	2.03	0.48	1.09 - 2.97
LCV's	0.63	0.13	0.38 - 0.88
Ratio of LCV to Non-LCV Rates	0.31	0.08	0.15 - 0.47
Difference Between LCV and Non-LCV Rates	1.40	0.46	0.50 - 2.30
Fleet Size (76-999)			
	Accident Rate	Standard Error	Confidence Interval
Non-LCV's	1.81	0.48	0.87 - 2.75
LCV's	1.31	0.17	0.98 - 1.64
Ratio of LCV to Non-LCV Rates	0.27	0.19	(0.10) - 0.64
Difference Between LCV and Non-LCV Rates	0.50	0.47	(0.42) - 1.42
Fleet Size (≥1000)			
	Accident Rate	Standard Error	Confidence Interval
Non-LCV's	1.76	0.14	1.49 - 2.03
LCV's	0.80	0.41	0.00 - 1.60
Ratio of LCV to Non-LCV Rates	0.45	0.22	0.02 - 0.88
Difference Between Non-LCV and LCV	0.96	0.36	0.25 - 1.67
ALL Carriers			
	Accident Rate	Standard Error	Confidence Interval
Non-LCV's	1.79	0.14	1.52 - 2.06
LCV's	0.88	0.19	0.51 - 1.25
Ratio of LCV to Non-LCV Rates	0.49	0.10	0.29 - 0.69
Difference Between LCV and Non-LCV Rates	0.91	0.19	0.54 - 1.28

When fatal-and-injury accidents were examined together, the LCV accident rate was 50 percent lower than the Non-LCV rate; this is consistent with study's findings generally — namely, that the LCV accident rate is approximately 50 percent of the Non-LCV rate. In this case, the difference in rates *was* statistically significant.

Table 11. Percentage of LCV and Non-LCV accidents by accident class.

Accident Class	Non-LCV's	LCV's	All Configurations
Fatal Accidents	1.4%	2.5%	1.5%
Fatal-and-Injury Accidents	13.7%	13.8%	13.7%
All Accidents	100.0%	100.0%	100.0%

Table 12. Accident rates by vehicle configuration and accident class: accidents per million VMT.

Configuration	Fatal	Fatal and Injury
Singles (Tractors-Semitrailers)	0.036	0.349
STAA Doubles (≤80,000 lbs)	0.006	0.090
Total Non-LCV's	**0.024**	**0.243**
STAA Doubles (>80,000 lbs.)	0.000	0.284
Rocky Mountain Doubles	0.027	0.137
Turnpike Doubles	0.053	0.212
Total LCV Doubles	***0.031***	***0.163***
Triples	0.007	0.045
Other LCV's	0.000	0.408
Total LCV's	**0.021**	**0.116**
Total All Vehicles	**0.022**	**0.196**

Table 13. Differences in LCV and Non-LCV accident rates by accident class. (Confidence level: 95%)

Fatal Accidents			
	Accident Rate	**Standard Error**	**Confidence Interval**
Non-LCV's	0.024	0.007	0.010 - 0.038
LCV's	0.021	0.007	0.007 - 0.035
Ratio of LCV to Non-LCV Rates *	0.860	0.350	0.174 - 1.546
Difference Between LCV and Non-LCV Rates	0.003	0.009	(0.015) - 0.021
Fatal-And-Injury Accidents			
	Accident Rate	**Standard Error**	**Confidence Interval**
Non-LCV's	0.25	0.05	1.52 - 0.35
LCV's	0.12	0.03	0.06 - 0.18
Ratio of LCV to Non-LCV Rates *	0.47	0.11	0.25 - 0.69
Difference Between LCV and Non-LCV Rates	0.13	0.05	0.03 - 0.23
All Accidents			
	Accident Rate	**Standard Error**	**Confidence Interval**
Non-LCV's	1.77	0.28	1.22 - 2.32
LCV's	0.83	0.19	0.46 - 1.20
Ratio of LCV to Non-LCV Rates *	0.47	0.11	0.25 - 0.69
Difference Between LCV and Non-LCV Rates	0.94	0.27	0.41 - 1.47

* Ratios shown may vary from the calculated values due to rounding.

4.3.4 Collisions Versus Non-Collisions

Although most accidents entailed collisions, LCV's were far less likely that Non-LCV's to be involved in either collisions or non-collisions; the differences in rates were statistically significant. Also, there were statistically meaningful differences in the collision rates of Rocky Mountain Doubles versus Turnpike Doubles and Rocky Mountain Doubles versus STAA Doubles Over 80K. LCV's appeared to have a higher probability than Non-LCV's of overturning, and LCV Doubles were more likely than Tractors-Semitrailers to jackknife.

Aggregate Rates. Figure 12 compares the incidence of *collisions* and *non-collisions* for LCV's and Non-LCV's.[16] The data show that Non-LCV's were 2.1 times more likely than LCV's to be involved in collisions, and 1.8 times more likely to be involved in non-collisions.

Table 14 summarizes the collision/non-collision rates for individual vehicle configurations. Among all vehicle types, Tractors-Semitrailers had the highest collision rate (1.54), followed by STAA Doubles Over 80K (1.42); Rocky Mountain Doubles had the lowest collision rate (0.45). Except for STAA Doubles Over 80K, the LCV configurations had lower-than-average probabilities of being involved in non-collisions: Rocky Mountain Doubles (0.34), Turnpike Doubles (0.27), and Triples (0.32).

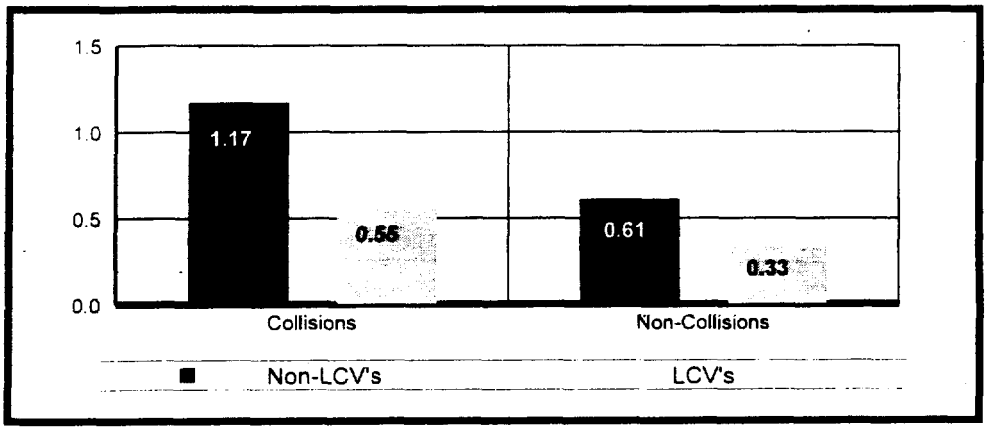

Figure 12. Collision and non-collision rates by configuration.

Turnpike Doubles were 69 percent more likely than Rocky Mountain Doubles to be involved in collisions. On the other hand, Rocky Mountain Doubles were 26 percent more likely than Turnpike Doubles to be involved in non-collisions.

Collisions By Type. Collisions were subdivided into two types: (1) *collisions with fixed objects*, and (2) *collisions with moving objects*. Table 15 shows accident rates, by vehicle configuration, for each collision type.

Non-Collisions By Type. Non-collisions were divided into these types: (1) *cargo shifts*, (2) *cargo spills*, (3) *jackknifes*, (4) *vehicle overturns*, (5) *running-off-the-road*, (6) *separation-of-units*, and (7) *fires*. Table 17 shows accident rates, by vehicle configuration, for each non-collision type.[17]

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[16] Eighty-four percent of the total accidents examined in this study were determined, definitively, to have involved collisions or non-collisions. The data presented in this section of the report are limited to those records where collisions and non-collisions could be distinguished from one another.

[17] None of the accidents examined in this study involved fire as the primary incident; therefore, "fire" is not shown in the table.

Table 14. Accident rates by configuration and collisions/non-collisions: accidents per million VMT.

Configuration	Collisions	Non-Collisions	All Accidents
Singles (Tractors-Semitrailers)	1.54	0.39	1.93
STAA Doubles (≤80,000 lbs)	0.94	0.76	1.70
Total Non-LCV's	**1.17**	**0.61**	**1.79**
STAA Doubles(>80,000 lbs.)	1.42	0.79	2.21
Rocky Mountain Doubles	0.45	0.34	0.79
Turnpike Doubles	0.76	0.27	1.02
Total LCV Doubles	***0.57***	***0.35***	***0.92***
Triples	0.51	0.32	0.83
Other LCV's	0.61	0.00	0.61
Total LCV's	**0.55**	**0.33**	**0.88**
Total All Vehicles	**1.04**	**0.55**	**1.59**
LCV Accident Rate As Percentage of Non-LCV Rate	**46.6%**	**53.8%**	**49.1%**

According to the data, LCV's were 1.9 times more likely than Non-LCV's to overturn; STAA Doubles Over 80K were much more likely than the other vehicle configurations to be involved in separation-of-unit accidents. Also, LCV Doubles were more likely than Tractors-Semitrailers to jackknife.

Statistical Significance. Table 16 examines the differences in collision and non-collision rates for LCV's and Non-LCV's. The data reveal that, in 95 percent of all cases among the study population, the LCV and Non-LCV collision rates would be expected to differ by 0.33 to 0.91 accidents per million VMT. Similarly, the LCV and Non-LCV non-collision rates would be expected to differ by 0.08 to 0.48 accidents per million VMT. These differences in rates were statistically significant.

Tables 18 and 19 compare differences in the collision and non-collision rates among the various vehicle configurations. While there were no meaningful differences in the non-collision rates among the LCV configurations (Table 19), there were differences in the collision rates (Table 18). The collision rates between Rocky Mountain Doubles and Turnpike Doubles — and Rocky Mountain Doubles and STAA Doubles Over 80K — were different, and these differences were statistically significant. The differences in collision rates between Triples and the other LCV configurations, however, were not significant.

Table 15. Accident rates by configuration and collision type: accidents per million VMT.

Configuration	Collision with Fixed Object	Collision With Moving Object	All Carriers
Singles (Tractors-Semitrailers)	0.21	1.32	1.54
STAA Doubles (≤80,000 lbs)	0.09	0.85	0.94
Total Non-LCV's	**0.14**	**1.04**	**1.17**
STAA Doubles (>80,000 lbs.)	0.17	1.25	1.42
Rocky Mountain Doubles	0.04	0.40	0.45
Turnpike Doubles	0.01	0.74	0.76
Total LCV Doubles	***0.04***	***0.53***	***0.57***
Triples	0.02	0.50	0.51
Other LCV's	0.00	0.61	0.61
Total LCV's	**0.03**	**0.51**	**0.55**
Total All Vehicles	**0.11**	**0.92**	**1.04**
LCV Accident Rate As Percentage of Non-LCV Rate	**22.7%**	**49.7%**	**46.6%**

Table 16. Summary of differences in mean collision and non-collision rates among LCV and Non-LCV configurations. (Confidence level: 95%)

Collision Accidents			
	Rate	**Standard Error**	**Confidence Interval**
Ratio of LCV to Non-LCV Rates	0.47	0.11	0.25 - 0.69
Difference Between LCV and Non-LCV Rates	0.62	0.15	0.33 - 0.91
Non-Collision Accidents			
	Rate	**Standard Error**	**Confidence Interval**
Ratio of LCV to Non-LCV Rates	0.54	0.12	0.31 - 0.78
Difference Between LCV and Non-LCV Rates	0.28	0.10	0.08 - 0.48

Table 17. Accident rates by configuration and non-collision type: accidents per million VMT.

Configuration	Cargo Shifts	Cargo Spills	Jackknifes	Vehicle Overturns	Running-Off-the-Road	Separation of Units	All Non-Collision Accidents
Singles (Tractors-Semitrailers)	0.002	0.016	0.062	0.110	0.044	0.010	0.391
STAA Doubles (≤80,000 lbs)	0.000	0.001	0.109	0.095	0.127	0.003	0.756
Total Non-LCV's	**0.001**	**0.007**	**0.091**	**0.101**	**0.095**	**0.006**	**0.614**
STAA Doubles(>80,000 lbs.)	0.000	0.000	0.114	0.454	0.057	0.170	0.795
Rocky Mountain Doubles	0.000	0.000	0.075	0.177	0.084	0.004	0.342
Turnpike Doubles.	0.000	0.013	0.053	0.159	0.040	0.000	0.266
Total LCV Doubles	***0.000***	***0.003***	***0.072***	***0.188***	***0.072***	***0.013***	***0.349***
Triples	0.000	0.000	0.028	0.201	0.010	0.003	0.316
Other LCV's	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Total LCV's	**0.000**	**0.002**	**0.051**	**0.193**	**0.043**	**0.008**	**0.330**
Total All Vehicles	**0.001**	**0.006**	**0.082**	**0.121**	**0.083**	**0.006**	**0.553**
LCV Accident Rate As Percentage of Non-LCV Rate	**0.0%**	**24.3%**	**55.7%**	**191.1%**	**44.9%**	**140.2%**	**53.8%**

Table 18. Differences in mean collision rates among LCV and Non-LCV configurations. (Confidence level: 95%)

18-1. Differences in collision rates between Singles (Tractors-Semitrailers) and other vehicle configurations.

Configuration	Accident Rate Difference	Standard Error	Confidence Interval
STAA Doubles (≤80,000 lbs)	0.59	0.32	(0.04) - 1.22
STAA Doubles (>80,000 lbs)	0.12	0.47	(0.80) - 1.04
Rocky Mountain Doubles	1.09	0.34	0.42 - 1.76
Turnpike Doubles	0.78	0.34	0.11 - 1.45
Triples	1.02	0.38	0.28 - 1.76
Other LCV's	[illegible]2	0.67	(0.39) - 2.23

18-2. Differences in collision rates between STAA Doubles (≤80,000 lbs) and other vehicle configurations.

Configuration	Accident Rate Difference	Standard Error	Confidence Interval
Singles (Tractors-Semitrailers)	-0.59	0.32	(1.22) - 0.04
STAA Doubles (>80,000 lbs)	-0.48	0.47	(1.40) - 0.44
Rocky Mountain Doubles	0.49	0.12	0.25 - 0.73
Turnpike Doubles	0.18	0.13	(0.07) - 0.43
Triples	0.43	0.26	(0.08) - 0.94
Other LCV's	0.33	0.58	(0.81) - 1.47

18-3. Differences in collision rates between STAA Doubles (>80,000 lbs) and other vehicle configurations.

Configuration	Accident Rate Difference	Standard Error	Confidence Interval
Singles (Tractors-Semitrailers)	-0.12	0.47	(1.04) - 0.80
STAA Doubles (≤80,000 lbs)	0.48	0.47	(0.44) - 1.40
Rocky Mountain Doubles	0.97	0.47	0.05 - 1.89
Turnpike Doubles	0.66	0.48	(0.28) - 1.60
Triples	0.91	0.35	0.22 - 1.60
Other LCV's	0.81	0.74	(0.64) - 2.26

11-4. Differences in collision rates between Rocky Mountain Doubles and other vehicle configurations.

Configuration	Accident Rate Difference	Standard Error	Confidence Interval
Singles (Tractors-Semitrailers)	-1.09	0.34	(1.76) - (0.42)
STAA Doubles (≤80,000 lbs)	-0.49	0.12	(0.73) - (0.25)
STAA Doubles (>80,000 lbs)	-0.97	0.47	(1.89) - (0.05)
Turnpike Doubles	0.31	0.14	0.04 - 0.58
Triples	-0.06	0.31	(0.67) - 0.55
Other LCV's	-0.16	0.58	(1.30) - 0.98

Table 18 (Cont'd.). Differences in mean collision rates among LCV and Non-LCV configurations. (Confidence level: 95%)

18-5. Differences in collision rates between Turnpike Doubles and other vehicle configurations.			
Configuration	**Accident Rate Difference**	**Standard Error**	**Confidence Interval**
Singles (Tractors-Semitrailers)	-0.78	0.34	(1.45) - (0.11)
STAA Doubles (≤80,000 lbs)	-0.18	0.13	(0.43) - 0.07
STAA Doubles (>80,000 lbs)	-0.66	0.48	(1.60) - 0.28
Rocky Mountain Doubles	-0.31	0.14	(0.58) - (0.04)
Triples	0.24	0.32	(0.39) - 0.87
Other LCV's	-0.14	0.59	(1.30) - 1.02

18-6. Differences in collision rates between Triples and other vehicle configurations.			
Configuration	**Accident Rate**	**Standard Error**	**Confidence**
Singles (Tractors-Semitrailers)	-1.02	0.38	(1.76) - (0.28)
STAA Doubles (≤80,000 lbs)	-0.43	0.26	(0.94) - 0.08
STAA Doubles (>80,000 lbs)	-0.91	0.35	(1.60) - (0.22)
Rocky Mountain Doubles	0.06	0.31	(0.55) - 0.67
Turnpike Doubles	-0.24	0.32	(0.87) - 0.39
Other LCV's	0.10	0.65	(1.17) - 1.37

18-7. Differences in collision rates between Other LCV's and other vehicle configurations.			
Configuration	**Accident Rate**	**Standard Error**	**Confidence**
Singles (Tractors-Semitrailers)	-0.92	0.67	(2.23) - 0.39
STAA Doubles (≤80,000 lbs)	-0.33	0.58	(1.47) - 0.81
STAA Doubles (>80,000 lbs)	-0.81	0.74	(2.26) - 0.64
Rocky Mountain Doubles	0.16	0.58	(0.98) - 1.30
Turnpike Doubles	0.14	0.59	(1.02) - 1.30
Triples	-0.10	0.65	(1.37) - 1.17

Table 19. Differences in mean non-collision rates among LCV and Non-LCV configurations. (Confidence level: 95%)

19-1. Differences in non-collision rates between Singles (Tractors-Semitrailers) and other vehicle configurations.

Configuration	Accident Rate Difference	Standard Error	Confidence Interval
STAA Doubles (≤80,000 lbs)	- 0.37	0.10	(0.57) - (0.17)
STAA Doubles (>80,000 lbs)	-0.40	0.34	(1.07) - 0.27
Rocky Mountain Doubles	0.05	0.12	(0.19) - 0.29
Turnpike Doubles	-0.13	0.09	(0.31) -0.05
Triples	-0.07	0.11	(0.29) - 0.15
Other LCV's	0.39	0.09	0.21 - 0.57

19-2. Differences in non-collision rates between STAA Doubles (≤80,000 lbs) and other vehicle configurations.

Configuration	Accident Rate Difference	Standard Error	Confidence Interval
Singles (Tractors-Semitrailers)	0.37	0.10	0.17 - 0.57
STAA Doubles (>80,000 lbs)	0.04	0.37	(0.69) - 0.77
Rocky Mountain Doubles	0.41	0.16	0.10 - 0.72
Turnpike Doubles	0.49	0.15	0.20 - 0.78
Triples	-0.44	0.13	(0.69) - (0.19)
Other LCV's	0.76	0.13	0.51 - 1.01

19-3. Differences in non-collision rates between STAA Doubles (>80,000 lbs) and other vehicle configurations.

Configuration	Accident Rate Difference	Standard Error	Confidence Interval
Singles (Tractors-Semitrailers)	0.40	0.34	(0.27) - 1.07
STAA Doubles (≤80,000 lbs)	-0.04	0.37	(0.77) - 0.69
Rocky Mountain Doubles	0.45	0.36	(0.26) - 1.16
Turnpike Doubles	0.53	0.33	(0.12) - 1.18
Triples	-0.48	0.37	(1.21) - 0.25
Other LCV's	0.79	0.34	0.12 - 1.46

19-4. Differences in non-collision rates between Rocky Mountain Doubles and other vehicle configurations.

Configuration	Accident Rate Difference	Standard Error	Confidence Interval
Singles (Tractors-Semitrailers)	-0.05	0.12	(0.29) - 0.19
STAA Doubles (≤80,000 lbs)	-0.41	0.16	(0.72) - (0.10)
STAA Doubles (>80,000 lbs)	-0.45	0.36	(1.16) - 0.26
Turnpike Doubles	0.08	0.11	(0.14) - 0.30
Triples	-0.03	0.17	(0.36) - 0.30
Other LCV's	0.34	0.09	0.16 - 0.52

Table 19 (Cont'd.). Differences in mean non-collision rates among LCV and Non-LCV configurations. (Confidence level: 95%)

19-5. Differences in non-collision rates between Turnpike Doubles and other vehicle configurations.			
Configuration	**Accident Rate Difference**	**Standard Error**	**Confidence Interval**
Singles (Tractors-Semitrailers)	0.13	0.09	(0.05) - 0.31
STAA Doubles (≤80,000 lbs)	-0.49	0.15	(0.78) - (0.20)
STAA Doubles (>80,000 lbs)	-0.53	0.33	(1.18) - 0.12
Rocky Mountain Doubles	-0.08	0.11	(0.30) - 0.14
Triples	0.05	0.15	(0.24) - 0.34
Other LCV's	-0.27	0.05	(0.37) - (0.17)

19-6. Differences in non-collision rates between Triples and other vehicle configurations.			
Configuration	**Accident Rate**	**Standard Error**	**Confidence**
Singles (Tractors-Semitrailers)	0.07	0.11	(0.15) - 0.29
STAA Doubles (≤80,000 lbs)	0.44	0.13	0.19 - 0.69
STAA Doubles (>80,000 lbs)	0.48	0.37	(0.25) - 1.21
Rocky Mountain Doubles	0.03	0.17	(0.30) - 0.36
Turnpike Doubles	-0.05	0.15	(0.34) - 0.24
Other LCV's	0.32	0.14	0.05 - 0.59

19-7. Differences in non-collision rates between Other LCV's and other vehicle configurations.			
Configuration	**Accident Rate**	**Standard Error**	**Confidence**
Singles (Tractors-Semitrailers)	-0.39	0.09	(0.57) - (0.21)
STAA Doubles (≤80,000 lbs)	-0.76	0.13	(1.01) - (0.51)
STAA Doubles (>80,000 lbs)	-0.79	0.34	(1.46) - (0.12)
Rocky Mountain Doubles	-0.34	0.09	(0.52) - (0.16)
Turnpike Doubles	0.27	0.05	0.17 - 0.37
Triples	-0.32	0.14	(0.59) - (0.05)

4.3.5 Threshold Accidents

The data and analyses presented elsewhere in this report cover all *accidents*. For informational and comparative purposes, however, Figure 13 and Table 20 show accident rates calculated when only *threshold accidents* — i.e., those accidents resulting in fatalities, injuries, or commercial vehicle tow-aways — are considered. Figure 13 compares overall LCV and Non-LCV threshold rates, while Table 20 shows the threshold rates, by fleet size, for individual vehicle configurations. It was not practical, generally, to perform more detailed analyses on the threshold data — the volume of accidents dropped precipitously when the non-threshold crashes were stripped off.

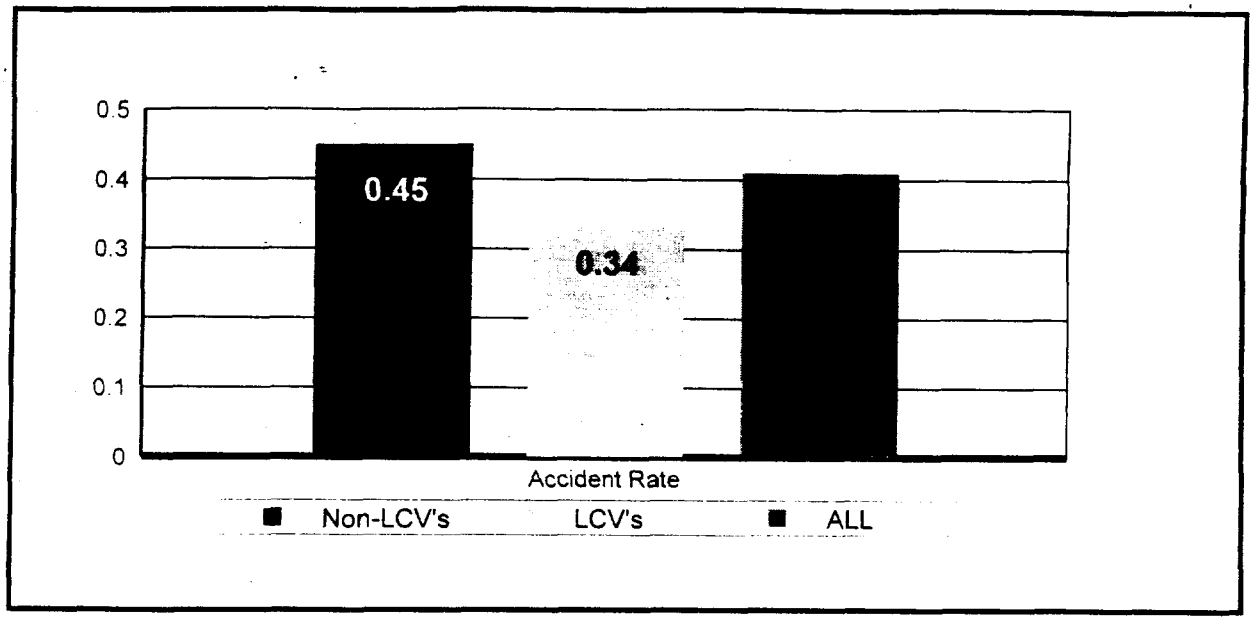

Figure 13. LCV versus Non-LCV accident rates: threshold accidents per million VMT

Table 20. Accident rates by configuration and fleet size: threshold accidents per million VMT.

	Fleet Size				
Configuration	**≤20**	**21-75**	**76-999**	**≥ 1,000**	**All Carriers**
Singles (Tractors-Semitrailers)	0.67	0.66	0.53	0.56	0.57
STAA Doubles(≤80,000 lbs)	0.00	0.91	0.43	0.16	0.27
Total Non-LCV's	**0.67**	**0.69**	**0.50**	**0.25**	**0.45**
STAA Doubles (>80,000 lbs.)	0.54	0.00	0.88	NA	0.74
Rocky Mountain Doubles	0.41	0.44	0.44	0.00	0.43
Turnpike Doubles	0.60	0.29	0.35	0.00	0.33
Total LCV Doubles	***0.46***	***0.42***	***0.45***	***0.00***	***0.42***
Triples	0.00	0.20	0.37	0.23	0.24
Other LCV's	0.00	1.40	0.00	NA	0.41
Total LCV's	**0.43**	**0.42**	**0.43**	**0.22**	**0.34**
Total All Vehicles	**0.57**	**0.56**	**0.49**	**0.24**	**0.41**
LCV Accident Rates As Percentage of Non-LCV Rate	**64.2%**	**60.9%**	**86.0%**	**87.1%**	**75.6%**

4.4 IMPACT OF VEHICLE CONFIGURATION ON ACCIDENT SEVERITY

Section 4.3.3 examined distribution of LCV and Non-LCV crashes among the three accident classes: fatal accidents, fatal-and-injury accidents, and all accidents. Here, the analysis focuses on differences in the severity of outcomes of accidents involving LCV's versus Non-LCV's. Specifically, accident outcomes are evaluated in terms of:

- *Fatalities.* Each person dying as a result of the accident was counted as a "fatality."
- *Injuries.* Each person requiring immediate medical treatment away from the accident scene was counted as an "injury."
- *Tow-Aways.* Each commercial vehicle which incurred disabling damage requiring a tow truck to remove it from the accident scene was counted as a "tow-away."

Fatalities, injuries, and tow-aways are compared in terms of occurrences per 100 accidents. All study accidents are included in this analysis, except those incidents for which outcome could not be determined.

4.4.1 LCV's Versus Non-LCV's

LCV's had accidents less frequently than Non-LCV's. When LCV accidents occurred, however, the outcomes tended to be more severe than when Non-LCV accidents happened. Notably, the incidence of fatalities per 100 LCV accidents was nearly twice as high as the Non-LCV rate.

Fatalities. As shown in Figure 14, the fatality rate for LCV's was 2.9 deaths per 100 accidents as compared to 1.5 deaths per 100 accidents for Non-LCV's. The fatality rate for Rocky Mountain Doubles (Table 21) was almost 90 percent higher than the rate for Tractors-Semitrailers, while the fatality rate for Turnpike Doubles was 150 percent higher than for Tractors-Semitrailers. The fatality rate for Triples, however, was 23 percent lower than the Tractor-Semitrailer rate.

Among the LCV configurations, the fatality rate for Turnpike Doubles was 32 percent higher than for Rocky Mountain Doubles. The overall fatality rate for LCV Doubles was 2.3 times higher than the rate for Triples.

Injuries. The overall rate of injuries remained relatively constant, regardless of whether LCV's or Non-LCV's were involved (Figure 15). Note, however, that the injury rate for Rocky Mountain Doubles (Table 21) was 27 percent higher than the rate for Turnpike Doubles. Indeed, comparisons of the outcomes of accidents involving Rocky Mountain Doubles and Turnpike Doubles might lead one to conjecture that sizable proportions of the injuries resulting from Rocky Mountain Double accidents ended up as fatalities when Turnpike Doubles were involved.

Of all LCV configurations, the injury rate for Triples was easily the lowest, averaging just six injuries per 100 accidents.

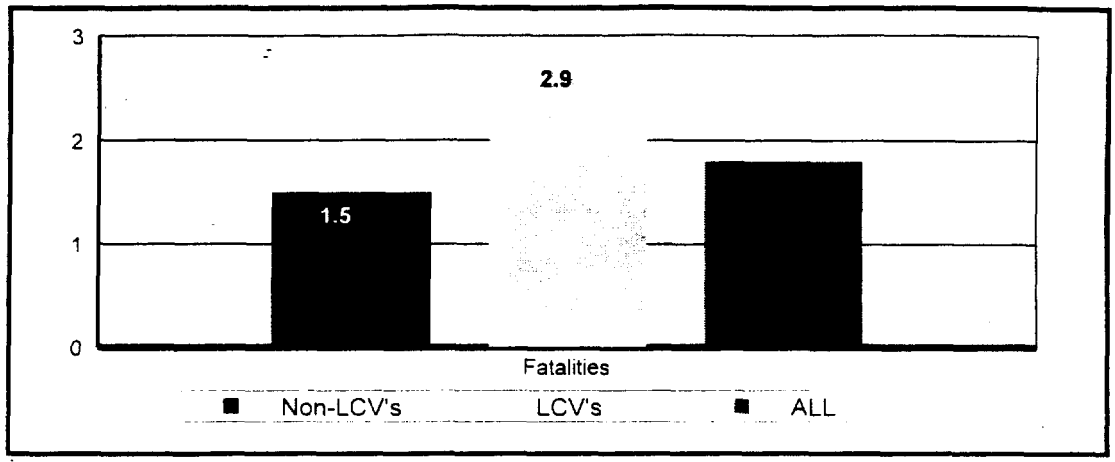

Figure 14. Accident severity by configuration: fatalities per 100 LCV/Non-LCV accidents.

Table 21. Accident severity by vehicle configuration: incidents per 100 accidents.

Configuration	Fatality Rate	Injury Rate	Tow-Away Rate
Singles (Tractors-Semitrailers)	2.08	22.00	20.69
STAA Doubles (≤80,000 lbs)	0.43	6.78	15.15
Total Non-LCV's	**1.51**	**16.71**	**18.77**
STAA Doubles (>80,000 lbs.)	0.00	23.08	25.64
Rocky Mountain Doubles	3.93	23.03	53.93
Turnpike Doubles	5.19	18.18	24.68
Total LCV Doubles	***3.74***	***21.77***	***42.52***
Triples	1.60	5.85	28.72
Other LCV's	0.00	66.67	66.67
Total LCV's	**2.89**	**15.88**	**37.32**
All Vehicles (Non-LCV's and LCV's)	**1.78**	**16.55**	**22.40**
LCV Rate As Percentage of Non-LCV Rate	**191.8%**	**95.0%**	**198.9%**

Tow-Aways. As indicated in Figure 16, the rate of tow-aways was nearly twice as high for LCV accidents than for Non-LCV accidents. Tow-away rates for the LCV configurations varied widely (Table 21) — from 25 per 100 accidents for Turnpike Doubles to 54 for Rocky Mountain Doubles; the tow-away rate for Triples was 29 per 100 accidents.

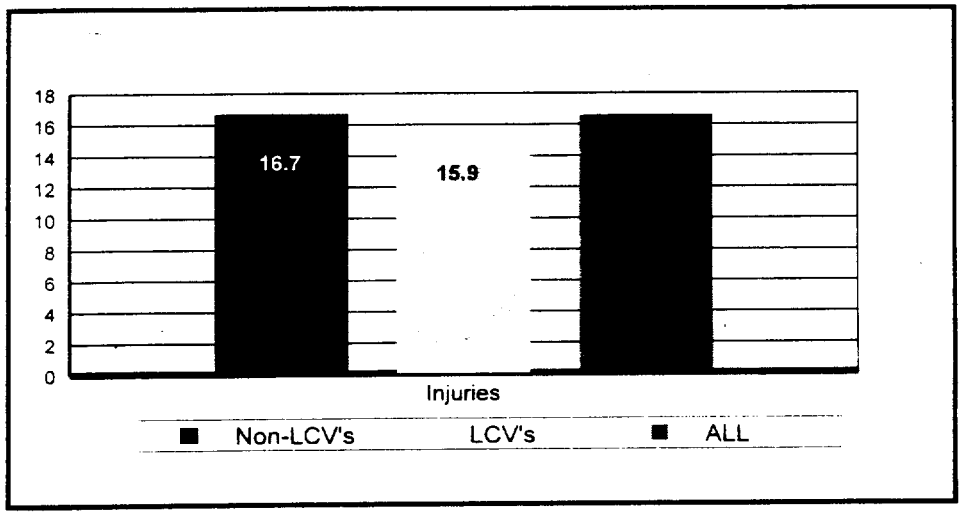

Figure 15. Accident severity by configuration: injuries per 100 LCV/Non-LCV accidents.

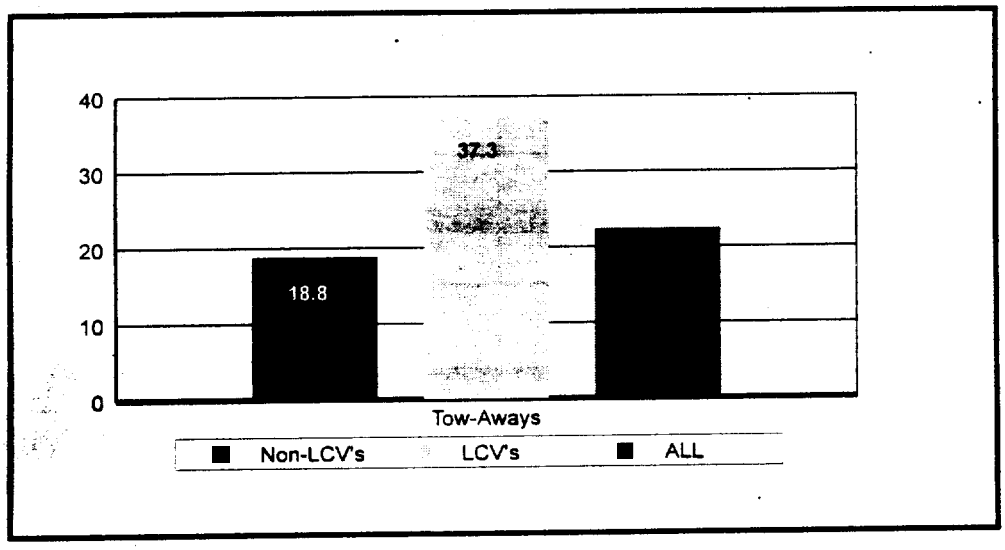

Figure 16. Accident severity by configuration: tow-aways per 100 LCV/Non-LCV accidents.

4.4.2 Collisions Versus Non-Collisions

Table 22 compares LCV/Non-LCV fatality rates for collision and non-collision accidents. In general, disparities in the severity of outcomes between LCV and Non-LCV accidents widened when collision accidents were isolated. Whereas the overall fatality rate for LCV's was 192 percent of the Non-LCV rate (Table 21), that rate jumped to 220 percent (Table 22) when only collisions accidents were examined. Similarly, the LCV overall injury rate, which was 95 percent of the Non-LCV rate, increased to 110 percent when only collisions were considered.

Table 22. Accident severity by vehicle configuration and accident type: incidents per 100 accidents.

Configuration	Collision Fatality Rate	Non-Collision Fatality Rate	Collision Injury Rate	Non-Collision Injury Rate
Singles (Tractors-Semitrailers)	2.26	1.04	23.01	26.42
STAA Doubles (≤80,000 lbs)	0.42	0.46	8.02	4.11
Total Non-LCV's	**1.71**	**0.73**	**17.27**	**14.56**
STAA Doubles (>80,000 lbs.)	0.00	0.00	36.00	0.00
Rocky Mountain Doubles	4.95	2.60	34.65	7.79
Turnpike Doubles	7.02	0.00	14.04	30.00
Total LCV Doubles	*4.92*	*1.80*	*28.42*	*10.81*
Triples	2.24	0.00	5.22	7.41
Other LCV's	0.00	0.00	66.67	0.00
Total LCV's	**3.75**	**1.21**	**19.06**	**9.70**
Total All Vehicles	**2.05**	**0.87**	**17.57**	**13.17**
LCV Rate As Percentage of Non-LCV Rate	**219.6%**	**166.5%**	**110.4%**	**66.6%**

4.5 IMPACT OF EXTERNAL FACTORS

The following "external" factors were examined in this study to assess their impact on LCV and Non-LCV accident rates:

- *Area* — Rural versus Urban,
- *Route* — Interstate versus Arterial,

- *Terrain* — Level versus Rolling/Mountainous,
- *Time-of-Day* — Daytime versus Nighttime, and
- *Driver Experience*.

As noted previously, analysis of these variables was limited by the study methodology. For one thing, many respondents could not apply precise definitions to the values associated with individual variables; hence, the reliability of a given respondent's estimate of the VMT travelled under the specified conditions was frequently low. For another, the size of the samples remaining after the unreliable or unavailable data were stripped off tended to be small. These constraints, collectively, limited the formalized statistical analyses which could properly be performed on these data.

4.5.1 Area

Table 23 shows the percentages of VMT and accidents in urban and rural settings. As expected, a high proportion of the LCV VMT — 88 percent — was accumulated in rural areas; however, a large percentage of the Non-LCV travel accrued by study participants — 70 percent — also occurred in rural areas. Most accidents, LCV and Non-LCV, occurred in rural settings.

Table 23. Distribution of VMT, accidents, and ratios by configuration and area.

	Rural Areas			Urban Areas		
Configuration	**VMT**	**Accidents**	**Ratio of Accidents to VMT**	**VMT**	**Accidents**	**Ratio of Accidents to VMT**
Non-LCV's	70.4%	54.0%	0.77	29.6%	46.0%	1.55
LCV's	87.9%	77.8%	0.89	12.1%	22.2%	1.83
All	74.2%	59.6%	0.80	25.8%	40.4%	1.57

Table 23 also compares the proportion of accidents to the proportion of VMT accrued in urban and rural settings. In both settings, LCV's experienced disproportionate numbers of accidents, although the difference was most pronounced in urban areas. The ratio of rural accidents to rural mileage was 0.89 for LCV's versus 0.77 for Non-LCV's. The ratio of urban accidents to urban mileage was 1.83 for LCV's versus 1.55 for Non-LCV's. These findings suggests that LCV's may be especially vulnerable to accidents when operated in and around urban areas. Note, however, that statistical assessment of these findings was not performed.

4.5.2 Route

As shown in Table 24, the bulk of the VMT — 66 percent — for both LCV's and Non-LCV's was accrued on interstate highways; 60 percent of the LCV travel occurred on interstate roads versus 68

percent of the Non-LCV travel. Table 24 also indicates apparent large differences in the LCV and Non-LCV accident-to-VMT ratios on interstate and arterial roads. The ratio on interstate highways for LCV's and Non-LCV's was 0.93 and 0.55, respectively; the ratio on arterial roads was 1.10 and 1.94, respectively. These findings suggest that although disproportionate numbers of accidents occurred on arterial roads, LCV's performed far better than Non-LCV's. On the other hand, on interstate highways, the accident experience of LCV's was comparatively poor. Statistical assessment of these findings was not performed.

Table 24. Distribution of VMT, accidents, and ratios by configuration and route.

	Interstate Roads			Arterial Roads		
Configuration	VMT	Accidents	Ratio of Accidents to VMT	VMT	Accidents	Ratio of Accidents to VMT
Non-LCV's	67.8%	37.6%	0.55	32.3%	62.4%	1.94
LCV's	59.5%	55.3%	0.93	40.5%	44.7%	1.10
All	66.0%	41.2%	0.62	34.0%	58.8%	1.73

4.5.3 Terrain

Seventy percent of the observable VMT in this study was accumulated on level terrain as opposed to rolling/mountainous terrain (Table 25). However, 41 percent of the LCV travel, versus 27 percent of the Non-LCV travel, was estimated to have occurred on rolling/mountainous terrain. In the case of the terrain factor, accidents tended to occur in direct proportion to the experienced VMT. Table 25 also shows that the accident-to-VMT ratio on rolling/mountainous terrain was slightly higher for LCV's (1.03) than for Non-LCV's (0.89). Statistical assessment of these findings was not performed.

Table 25. Distribution of VMT, accidents, and ratios by configuration and terrain.

	Level Terrain			Rolling/Mountainous Terrain		
Configuration	VMT	Accidents	Ratio of Accidents to VMT	VMT	Accidents	Ratio of Accidents to VMT
Non-LCV's	72.7%	75.8%	1.04	27.3%	24.2%	0.89
LCV's	59.4%	58.1%	0.98	40.6%	41.9%	1.03
All	69.8%	72.5%	1.04	30.2%	27.5%	0.91

4.5.4 Time-Of-Day

Study participants accrued half of all VMT — 51 percent — and half of all accidents — 53 percent — during nighttime travel (Table 26). As shown, the accident-to-VMT ratio for daytime travel was 1.10 for LCV's versus 0.94 for Non-LCV's; the pattern was reversed for nighttime travel: 0.91 for LCV's versus 1.06 for Non-LCV's. These findings imply that LCV's performed comparatively better at night than during the day. Again, statistical assessment of the findings was not performed.

Table 26. Distribution of VMT, accidents, and ratios by configuration and time-of-day.

	Daytime			Nighttime		
Configuration	VMT	Accidents	Ratio of Accidents to VMT	VMT	Accidents	Ratio of Accidents to VMT
Non-LCV's	49.5%	46.6%	0.94	50.5%	53.4%	1.06
LCV's	45.9%	50.7%	1.10	54.1%	49.3%	0.91
All	48.8%	47.1%	0.97	51.2%	52.9%	1.03

4.5.5 Driver Experience

Drivers of both LCV's and Non-LCV's possessed comparable professional driving experience, as evidenced by the distribution of VMT by driver experience (Table 27). Among the LCV configurations (Table 28), drivers of Triples possessed substantially more high-end experience than did drivers of LCV Doubles — 67 percent of all VMT associated with Triples was accrued by drivers with more than seven years professional driving experience; by contrast, only 40 percent of the miles for LCV Doubles were driven by drivers with over seven years experience.

The mean accident rates for LCV's and Non-LCV's by driver experience are presented in Table 29. The differences in the LCV and Non-LCV accident rates, and the standard errors and confidence intervals affiliated with these differences, are also shown.

Table 27. Distribution of VMT by configuration and driver experience.

Configuration	Driver Experience (In Years)				
	<1	1-3	3-5	5-7	≥7
Non-LCV's	9.2%	15.4%	16.1%	16.5%	42.8%
LCV's	6.5%	16.9%	15.2%	15.5%	45.9%
Total All Vehicles	8.4%	15.8%	15.9%	16.2%	43.7%

In general, the following observations may be made about the driver experience data:

- As driver experience increased, the rate of accidents tended to decrease, with one notable exception. The exception pertained to drivers with more than seven years professional driving experience.

- Drivers with less than one year professional driving experience had exceptionally high accident rates, regardless of whether they were driving LCV's or Non-LCV's. For these drivers, the LCV accident rate (2.85 accidents per million VMT) was higher than the Non-LCV rate (2.40 accidents per million VMT).

- Drivers with more than one year — but less than seven years — professional driving experience had fewer accidents.

- Accident rates declined at a faster pace for drivers of LCV's than drivers of Non-LCV's, as driver experience increased. The LCV/Non-LCV accident ratio went from 1.19 for drivers with less than one year experience to 0.47 for drivers with 5-7 years professional driving experience.

- Although LCV and Non-LCV accident rates increased for drivers with more than seven years experience, the accident rates for both vehicle configurations were virtually identical — 1.21 for Non-LCV's versus 1.20 for LCV's.

- The difference in LCV and Non-LCV accident rates was *marginally significant* for drivers with 1-3 years professional driving experience, and *significant* for drivers with 3-5 years experience.

Table 28. Distribution of VMT by LCV Doubles/Triples and driver experience.

Configuration	Driver Experience (In years)				
	<1	1-3	3-5	5-7	≥7
LCV Doubles	7.9%	19.2%	16.8%	16.6%	39.5%
Triples	1.8%	9.1%	10.2%	12.3%	66.6%
All LCV Doubles & Triples	6.5%	16.9%	15.2%	15.5%	45.9%

Based on these data, it might be supposed that among the less-experienced drivers, those with the best safety records were assigned to LCV's. On the other hand, the most-experienced drivers (i.e., those with seven or more years of professional driving experience) possessed comparable safety records; hence, there was less need to differentiate between which of those drivers were assigned to

LCV's. The fact that accident rates went up for the most-experienced driver group may be more a function of driver age than driver experience.

Table 29. Differences in LCV and Non-LCV accident rates by driver experience. (Confidence level: 95%)

	Driver Experience (In years)				
	<1	1-3	3-5	5-7	≥7
Non-LCV Accident Rate	2.40	1.71	1.52	0.79	1.21
LCV Accident Rate	2.85	0.74	0.77	0.37	1.20
Ratio of LCV to Non-LCV Rates	1.19	0.43	0.51	0.47	0.99
Difference Between LCV and Non-LCV Rates	0.45	0.97	(0.75)	(0.42)	(0.01)
Standard Error of Difference	1.56	0.56	0.33	0.28	0.24
Confidence Interval (Difference)	(2.61) - 3.51	(2.07) - 0.13	(1.40) - (0.10)	(0.97) - 0.13	(0.46) - 0.48

4.6 CARRIER-FURNISHED ANECDOTAL DATA

At the conclusion of site visits, carriers were invited to share their insights into the operational differences between LCV's and Non-LCV's. Key comments furnished by respondents are summarized below:

1. **Braking Performance.** Most respondents said that LCV's have more braking power than Non-LCV's. Even so, LCV's require longer stopping distances than Non-LCV's — the extra weight and additional axles on LCV's compel drivers to go slower in order to stop safely. Several respondents noted that the braking power and traction capabilities of Triples are superior to those of Doubles, due to shorter trailers and weight distributions. Triples, however, become more hazardous when their trailers — especially the rear-most trailers — are empty or cargo weight is not properly distributed.

2. **Maneuverability.** Extra length affects the maneuverability of LCV's, according to respondents. LCV's require more space for passing, changing lanes, and turning. Sharp turns may cause a "whipping effect" resulting in overturns. Additionally, extra length can cause rear trailers to off-track outside the travel lanes or overrun curbs during turns. Length

also impedes the backing-up of units. Several respondents said that Triples have tighter turning radii than Doubles, thereby decreasing the likelihood of "turning" accidents involving Triples.

3. **Trailer Sway.** Respondents complained of LCV rear-trailer sway, particularly when trailers are empty. Road surface conditions also contribute to the problem of sway: snow, ice, ruts, and grooves in the roads can make tracking difficult, leading to further sway. Some respondents noted that careful distribution of cargo between the front and rear trailers helps reduce the extent of sway.

4. **Speed.** LCV's require more horsepower to maintain traffic speed and overcome changes in elevation. LCV's need more distance to merge and change lanes, so travel in congested traffic is difficult.

5. **Driver Experience.** Respondents overwhelmingly agreed that drivers are the single most important factor in the safe operation of LCV's. According to respondents, only the most-skilled, most-experienced drivers are assigned to LCV's. Some carriers require their LCV drivers to attend training programs; others conduct occasional on-the-road monitoring, where the drivers are assessed on their performance and their ability to respond to constantly-changing on-road conditions. LCV drivers, respondents said, are encouraged to select safer routes, especially in adverse weather conditions.

5.0 SUMMARY AND CONCLUSIONS

In this study, the accident rates for LCV's and Non-LCV's were found to be different, and the differences were statistically significant. Among the 75 carriers studied, the LCV accident rate (0.88) was one-half the Non-LCV rate (1.79). There were also differences in the rates of accidents among LCV subgroups: STAA Doubles Over 80K had the highest rates (2.21) of any vehicle configurations examined; Rocky Mountain Doubles had the lowest rates (0.79), followed by Triples (0.83) and Turnpike Doubles (1.02). Differences in rates among the LCV subgroups, however, were not found to be statistically significant.

LCV's and Non-LCV's had equal probabilities of being involved in fatal crashes. However, LCV's were 50 percent less likely than Non-LCV's to be involved in accidents when fatal and injury crashes were examined in tandem. When LCV accidents occurred, the outcomes were decidedly more severe: the average number of fatalities per LCV accident was 90 percent higher than for each Non-LCV crash. Also, LCV accidents resulted in much higher tow-away rates than Non-LCV accidents.

LCV's were half as likely as Non-LCV's to be involved in collisions and non-collisions. Rocky Mountain Doubles were less likely than Turnpike Doubles and STAA Doubles Over 80K to be involved in collisions and, this time, the differences in rates were statistically significant. Among non-collision incidents, LCV's were more susceptible than Non-LCV's to vehicle overturns and separation-of-unit accidents.

What explains the differences in LCV and Non-LCV accident rates? Although several key external factors were examined in this study, no combination of factors came close to deciphering the results. One reason that explanatory factors were not detectable may relate to the size of subgroups within the study sample. For instance, although 40 percent of the sampled carriers operated fleets of 1-20 vehicles, these carriers accrued only two percent of the total VMT. Consequently, representation of smaller carriers in the sample may not have been large enough for differences in accident rates by fleet size to be discerned, even if those differences, in fact, existed.

A second reason that explanatory factors were not detectable may relate to the relative homogeneity of the population of carriers currently operating LCV's. These carriers operate predominantly in rural areas on arterial roads, possess far better safety fitness records than the carrier population at-large, and tend to assign exceptionally-experienced drivers to all their vehicles, whether LCV's or Non-LCV's. Hence, the high degree of congruity among the LCV carrier population may have confounded some of the analyses.

On this last point, the issue of driver experience merits discussion. A relationship in the data, in fact, existed between driver experience and accident rates — drivers with more experience tended to have fewer accidents. However, because the LCV and Non-LCV drivers had virtually identical professional experience, and yet the accident rates for the two groups were so very different, the "message" the data send — namely, that driver experience alone does not explain the total difference in accident rates — cannot be easily ignored.

Nevertheless, when the carriers participating in this study were asked, at the end of the site visits, to speculate about the primary factors influencing LCV safety, they overwhelmingly stated that the *driver* was key; that only the most-skilled, most-experienced drivers were assigned to LCV's. To reconcile these carrier statements with the study's quantitative findings, one is tempted to postulate that *driver experience* is an insufficient measure of a conglomeration of more complicated factors called, say, *driver maturity and driver skill*. This premise possibly warrants examination in future research.

There are several items which should be noted regarding the carrier population examined in this study. First, based on the validation analyses performed, it is reasonable to conclude that the carrier sample used here is reflective of the LCV carrier population identified by the 19 States. Secondly, no representation may be made, on the basis of study findings, regarding the extent to which the list of carriers furnished by the States actually comports with the universe of carriers operating LCV's.

Finally, these study findings make no predictions about the commercial vehicle accident rates which would result from changes in restrictions on LCV operations, or expansion of the carrier population utilizing LCV's. Rather, the findings represent a *snapshot* of accident rates as experienced during a six-year period by a relatively elite group of carriers functioning in predominantly rural settings. The carriers studied have, on average, safety fitness records vastly superior to the nation's carrier population at-large.

GLOSSARY

Accident: An occurrence involving a commercial motor vehicle operating on a public road in interstate or intrastate commerce which requires the filing of a police or insurance accident report, or the recording of information pertaining to the occurrence in the motor carrier's Accident Register.

Accident Class: Used to categorize commercial vehicle accidents according to accident severity. The three classes are: *Fatal Accidents*, *Fatal-and-Injury Accidents*, and *All Accidents*.

Accident Rate: The rate at which accidents meeting prescribed characteristics occur. In this report, rates are normalized per million vehicle miles of travel.

Accident Register: File containing documentation of accidents which motor carriers are required to maintain, as defined in the *FMCSR*, Part 390.15.

Accident Severity: The likelihood that accidents, when they occur, will involve fatalities or injuries. In this report, accident severity is normalized per 100 accidents.

Area: For purposes of this study, area is defined as either "Urban" or "Rural."

Collision Accident: An accident between a commercial motor vehicle and another object, including other motor vehicles, trains, bicycles, pedestrians, animals, and fixed objects along the roadway.

Domicile (State of): Refers to the State in which the motor carrier maintains its legal headquarters.

Driver Experience: The total professional driving experience for an individual driver; it refers to the aggregate number of years a driver has professionally operated commercial motor vehicles.

Fatal Accident: An accident for which at least one fatality was reported.

Fatal-And-Injury Accident: An accident involving fatalities, injuries, or both.

Fatality: A death resulting from a motor vehicle accident.

Federal Motor Carrier Safety Regulations (FMCSR): Regulations governing the safe operation of commercial vehicles engaged in interstate commerce. The *FMCSR* are contained in the *Code of Federal Regulations*, Title 49, Subtitle B, Chapter III.

Fleet Size: The total number of power units which a particular carrier owns or leases. Fleet size strata used in this study are: 1-20 power units; 21-76 power units; 77-999 power units; and 1,000 and more power units.

For-Hire Carrier: A commercial motor carrier whose primary business activity is the transportation, for compensation, of property by motor vehicle.

Hazardous Materials Regulations (HMR): Federal regulations governing the commercial transportation of hazardous materials. The *HMR* are contained in the *Code of Federal Regulations*, Title 49, Subtitle B, Chapter I.

Injury: Bodily injury resulting from a motor vehicle accident. To qualify as an "injury," the injured person must require immediate

medical treatment away from the accident scene.

Inspection: The systematic examination of a commercial motor vehicle and its driver to determine their overall safety fitness.

Interstate Carrier: A carrier who sometimes or always operates in interstate or foreign commerce.

Jackknife: A non-collision accident in which a tractor and its trailer slide together, forming a V-shaped angle of 90 degrees or less.

Longer Combination Vehicle (LCV): Any truck-tractor combination with (1) two or three trailers, and (2) a trailer length in excess of twin 28.5-foot trailers or a GVW in excess of 80,000 pounds.

Motor Carrier Management Information System (MCMIS): The computerized system, operated by FHWA, containing comprehensive safety data on interstate commercial carriers.

National Population: All commercial carriers identified by FHWA as operating in U.S. interstate commerce.

Non-Collision Accident: An accident in which the primary event did not involve another object; these accidents include jackknifes, overturns, fires, cargo shifts and spills, and running off the road.

Non-Longer Combination Vehicle (Non-LCV): For purposes of this report, Non-LCV configurations are catalogued either as Tractors-Semitrailers (Singles) or STAA Doubles 80,000 Pounds or Less.

OOS Violation Rate: The mean number of out-of-service violations per 100 inspections.

Out-of-Service (OOS) Violations: A violation of the *FMCSR* or *HMR* requiring that a commercial vehicle or driver be taken out-of-service, or moved off the road, until the circumstances which caused the violation have been resolved.

Private Carrier: A commercial motor carrier for which private highway transportation activities are incidental to, and only in furtherance of, its primary business activity.

Rocky Mountain Double: An LCV tractor-trailer-trailer combination with a 45-53 foot first trailer, and a 26-28.5 foot second trailer.

Route: For purposes of this study, route is either "Interstate" or "Arterial."

STAA Double: A tractor-trailer-trailer combination with 26-28.5 foot trailers. A STAA Double can be classified as either an LCV or a Non-LCV, depending on its gross vehicle weight.

Study Non-Participants: Those carriers invited to participate in the research who declined the invitations.

Study Participants: Those carriers who accepted the invitations to participate in the LCV research.

Study Population: Those carriers eligible to participate in the research, i.e., study participants and non-participants combined.

Terrain: For purposes of this study, terrain is either "Level" or "Rolling/Mountainous."

Threshold Accident: An occurrence involving a commercial motor vehicle operating on a public road which results in a fatality, bodily injury requiring medical treatment away from the scene of the accident, or one or

more commercial vehicles incurring disabling damage requiring the vehicle to be towed from the scene of the accident.

Time-Of-Day: For purposes of this report, time-of-day is "Daytime" or "Nighttime."

Tractor-Semitrailer: A Non-LCV tractor-trailer combination with 40-59.5 foot trailers.

Triple: An LCV tractor-trailer-trailer-trailer-combination with 26-28.5 foot trailers.

Turnpike Double: An LCV tractor-trailer-trailer combination with 45-48 foot trailers.

USDOT Number: An identification number assigned to all interstate commercial carriers regulated by FHWA. The number is used to track the safety records associated with a given carrier.

Vehicle Miles of Travel (VMT): The total miles accumulated by all power units operated (owned and leased) by a given carrier during a specified time period.

Violation: A violation of the *FMCSR* or *HMR*.

Violation Rate: The mean number of violations per 100 inspections.